# A study into contract strategies based on existing moveable bridge projects

The influence of project parameters and client characteristics on construction contracting.

Master thesis by

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# Preface

As a construction management & engineering master student I am particularly interested in the management of building projects. Selecting the right type of contract for a project can improve the building project and building process. The scope and nature of these projects can differ but all building projects have a legally binding contract. A contract in that sense secures the relation and agreements between the different parties involved in the project. A building contract is a complex document that captures the whole project, or parts of it, from cost and delivery date to the distribution of responsibilities and liabilities. A contract in that sense is the foundation for a project and nowadays a lot of (standard) contract types are available. Therefore, this master thesis is intended for decision makers, clients and (future) owners of moveable bridges who are interested in selecting the right type of contract for their project.

I would like to thank the everybody who supported me during this master thesis. Extra gratitude has to be assigned to the following people: prof. dr. ir. M.J.C.M. Hertogh, ir. L.P.I.M Hombergen and dr. ir. K.C. Terwel from the Technical University Delft for their support and input. Ir. M. Schroten from Flux Partners for the internship and his accompaniment during this master thesis. Last but not least, my girlfriend, the interviewees, my family and friends for their support and contribution to this master thesis.

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# Management summary

Currently there are a lot of contract types available for building projects. It is not always clear beforehand what type of contract a client should choose for his project. The goal of this study is to solve this problem by advising clients which type of contract to use for moveable bridge projects. Therefore, the following research question will be answered: *How does the model look like that predicts which type of contract is best for a moveable bridge project?* In order to answer this question, literature is studied and interviews are conducted to show which parameters and characteristics are of influence for this contract decision. This information is used to set up an initial model which advises what type of contract to use. This initial model is verified with the use of case projects in order to get the final model. Due to the wide range of building projects, this master thesis is focused on moveable bridges in the Netherlands only. Moveable bridges are multidisciplinary projects which makes the decision for a specific type of contract ambiguous. Making it the a perfect type of project to test the model.

The literature and interviews highlighted eleven criteria that are of influence for the types of contracts incorporated in the model. The contract types that are included in this model are: RAW-bestek, Design & Build, Design, Build & Maintain and Turnkey. The decision to incorporate these four contract types is based on the fact to include traditional and integrated contracts. RAW-bestek is the traditional contract type that is common to use for moveable bridges in the Netherlands. The choice for an integrated contract form for moveable bridges is bigger. Therefore, integrated contracts with different ranges of integration are included. Starting with Design & Build as a conventional integrated contract form followed by Design, Build & Maintain as a more integrated contract form and Turnkey as totally integrated contract form.

This initial model is verified with the use of four moveable bridge cases. For three of the case projects the model advised well. These projects went according plan and the advice from the model matched the contract that was actually used or the model highlighted the main headings for which the different incorporated contracts match the actually used contract. For example, case A used the contract type Engineer & Construct, this type of contract is not included in the model. The initial model showed exactly on which statements the Design, Build & Maintain contract and the RAW-bestek scored well for this case project. The statements on which they scored well are exactly the items for which an Engineer & Construct type of contract would be suited. If Engineer & Construct as a contract type would have been incorporated in the model, it would most likely be advised by the model. The verification of case B was not a match between the used type of contract and the advice from the initial model. The project did not went according to plan, but the advised type of contract would probably not have improved the situation. Several improvements are suggested based on comparison between this case and the other case projects.

It is concluded that the model is functioning, based on the cases. However, it is recommended to extend the model with more types of contracts, such as the contract type Design & Construct, Engineer & Construct and Bouwteam. The second recommendation comes from the ambiguity concerning the benchmark score for the criterion complexity. The positive correlation between complexity and flexibility was stated in literature, meaning that when the complexity of the project increases the need for more flexibility also increases. However, other literature contradicted this; it was unclear which viewpoint should be preferred. Therefore, the decision was made to adopt the positive correlation for the initial model. After verifying this initial model, the benchmark scores for

complexity were adjusted in order to be in line with the other literature. The advice from the initial model and the initial model adjusted for complexity were compared. However, based on this comparison no firm conclusion can be made about which viewpoint is preferred over the other concerning complexity. Therefore, it is recommended to further verify the model for the criterion of complexity. Furthermore, it is recommended to verify this model with more moveable bridges and cases for other types of projects in order to increase the validity, usability and applicability of the model.

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# 1. Introduction

Construction projects are increasing in complexity and various specific demands are put forward by clients. Combined with the desires for minimum building cost, maximum building speed and a stated building quality, the pressure on construction projects becomes higher and higher every day. A wrong type of contract can ruin your project's success. Does this also work the other way around? More specifically, can an optimal type of contract increase the output of your project? With that question in mind, this study is performed.

## 1.1 Problem definition

There are a lot of moveable bridges in the Netherlands (Antea group) for which governmental bodies are liable. These governmental bodies are not always equipped with the knowledge concerning the procurement which becomes necessary in cases such as renovation or building a new moveable bridge (Luu, Thomas Ng, & Chen, 2003). Currently, there is no model predicting what type of contract is the optimal one for a moveable bridge project. Contracting authorities have to choose a certain type of contract based on unilateral information. This decision might not always result in the optimal type of contract.

## 1.2 Thesis objective

The objective is to make a functional model that advises clients which type of contract to use in a specific situation. To create such a model, it is important to establish what parameters or criteria are important and should be used as input for the model. Literature will be studied and interviews will be conducted in order to show the parameters and characteristics to use. This initial model must be verified and possibly adjusted based on case studies. The case studies under investigation are ideally of similar nature and/or scope but realised with different types of contracts. That way objective verification and fine tuning of the model is possible, which will increase the usability of the model. In the end, the model should help to choose a type of contract depending on the clients contract strategy.

## 1.3 Research question

Based on the problem definition and the thesis objective the following research question is stated:

*How does the model look like that predicts which type of contract is best for a moveable bridge project?*

In order to answer the research question, the following sub-questions are defined.

### Sub-questions
1. Which project parameters are of influence on the procurement? (key parameters)
2. How is the (involvement of the) client of influence on the procurement? (client style)
3. Does the initial model, based on sub-questions 1 and 2, comply with real cases? (verification of the model)

## 1.4 Research methodology

The setup for this research:

- Literature will be studied for important criteria and how these criteria are interpreted and defined.
- Interviews will be carried out to enrich the literature and check the literature for applicability in the Dutch moveable bridge sector.
- Selecting and defining of criteria to be incorporated in the model based on the literature and interviews
- Creation of an initial model (based on the literature and interviews)
- Verification of the initial model by moveable bridge cases
- Possible adjustments to the initial model
- Conclusion and recommendations

## 1.5 Project scope

To provide an answer to the research question the verification will focus on the after-construction phase of contracts. The focus is on the after construction phase, because then the entire construction of the building is finished and possible maintenance and operation can be taken in consideration. This way a useful and functioning model should be realised.

The decision to focus on moveable bridges is made because of the following reasons. First, the availability of case projects that are willing to conduct an interview. Moveable bridge projects that can be used as a case are frequently executed in the Netherlands. The verification of the initial model can be done with the use of different moveable bridge cases. Secondly, the decision to use moveable bridges comes down to the fact that moveable bridges are multidisciplinary projects, meaning collaboration between multiple disciplines in one project, which adds complexity to the contract strategy. In third place, moveable bridges are realised with different types of contracts, meaning that the model can be verified for different types of contracts for the same type of project. One is not comparing apples with oranges, because only moveable bridges are compared in the verification process. This gives the ability to compare the results between the verifications in detail. Last but not least, the large diversity in types of project forced this research to focus on a specific type of project.

The following four contract types are included in this research: RAW-bestek, Design & Build, Design, Build & Maintain and Turnkey. The decision to incorporate these four contract types is based on the fact to include traditional and integrated contracts. RAW-bestek is the traditional contract type that is common used in the Netherlands for ground, road and water works, the GWW sector in Dutch. This type is a common type of contract to use for moveable bridges. The choice for integrated contract types for moveable bridges is bigger. It was decided to include integrated contracts with different ranges of integration. Starting with Design & Build as a conventional integrated contract form followed by Design, Build & Maintain as a more integrated contract form and Turnkey as totally integrated contract form. It is decided to not include more contract types in this initial model in order to first verify the functioning of the model before making it comprehensive. In following order from traditional to most integrated form is, RAW-bestek, Design & Build, Design, Build & Maintain and Turnkey. This is also visible in figure 1 degree of integration.

RAW-bestek                              Design & Build    Desing, Build & Maintain    Turnkey

Traditional                                               Integrated

⇨
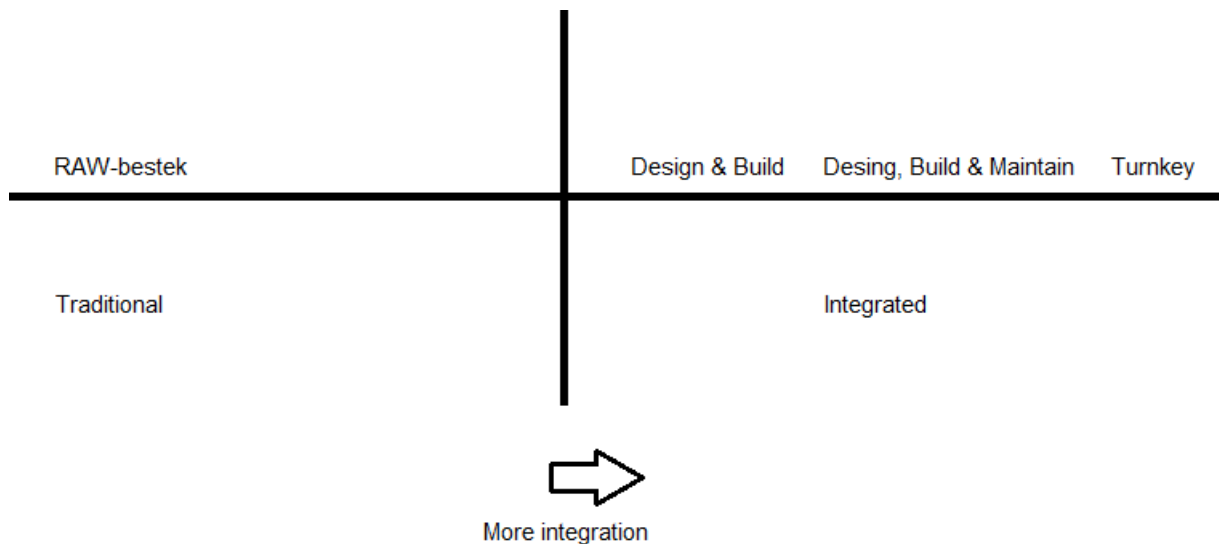
More integration

**Figure 1 Degree of integration**

In order to avoid any ambiguity concerning the types of contracts and their names that are used in the model they are clarified. Lump Sum is the traditional type of contract for building projects, the characteristics of this type of contract best match the RAW-bestek for moveable bridge projects in the Netherlands. The integrated contract forms: Design & Build, Design, Build & Maintain and Turnkey are similar for the Dutch situation as they are in the English situation. This clarification is important since Lump Sum could also refer to Lump Sum Turnkey, which is not the case for this study, Lump Sum is a traditional contract and Turnkey is an integrated contract.

## 1.6 Relevance

Building projects do not always go as planned, in most cases, one or more of Atkinson's success criteria (time, cost and quality) are not up to the desired level (Atkinson, 1999). Projects can be delayed, over-budget or do not meet the required specifications. As long as building projects are undertaken, things might go different than initially planned. Reasons for these deviations can be numerous, from location related sources to miscommunication between client and contractor. By choosing the best type of contract for the project, the client and contractor have the tools and possibility to solve these problems in an effective way. The use of this model should lead to a higher success-rate of moveable bridge projects.

# 2. Literature study

## 2.1 Introduction

The main goal of this literature study is to find out which project and/or client characteristics are important when selecting the type of contract. These characteristics are called criteria in most articles. But before we dive into the literature, a small comparison between the historical and the current ways of procuring is made. After this intermezzo the literature study will be provided, followed by a conclusion of the literature.

Gabri van Tussenbroek highlights in his work 'alzo zij gijlieden dat maken' (Bleeker, 2015) the historic ways of procuring. His research showed that similar contract forms, as used nowadays, were used in the period between 1391 till 1650. Specifications written by the client comparable with the current RAW-bestek and also price requests for which different designs were submitted comparable with Design & Construct. At that time, it was possible to resubmit and underbid competing contractors within a certain time frame. There are examples of buildings being pre-funded by the builder, similar to the current 'Finance' component in some integrated contracts. Nowadays, clients can choose between traditional and integrated contracts and even within these categories a lot of variants are available. At first sight the current procurement sector might seem very overwhelming, full of traditional contracts and recently developed integrated contract types, however, according to the research by Gabri van Tussenbroek, the current procurement sector has some similarities with the past. Still it might be unclear what type of contract best suits a specific project.

## 2.2 Literature

The papers included in this literature study date back as far as the 1980's. Despite the oldest papers being already 30 years old, they still form a good starting point for this thesis. A complete overview of all the papers and the (ranked) criteria is included in appendix A and in table 5 at the end of this chapter. In order to show the progress that was made throughout the years in subsequent papers, the papers in table 5 and appendix A are ordered chronologically. In case there is a ranking order for the criteria, then this ranking is also visible, the most important criterion has a 1 and the second most important a 2 and so on.

The articles for this literature study were mainly searched with the use of Google Scholar. Searching was done by combining terms such as: building contracting, construction contracting, building procurement, construction procurement, procurement criteria building project, contracting criteria and so on. Furthermore, the reference lists from the articles were used as a stepping stone to eventually find the articles which are used in this literature study.

Research into what influences the contract strategy started in the 1980s in England. The National Economic Development Office (NEDO) aimed to alter the relative economic decline in England by improving the communication between management, government and trade unions. This institute has written several reports of which the report 'Thinking about building' from 1985 initiated thinking in criteria (Designing buildings, 2016). This report mentions nine criteria for the client to determine the project priorities. These nine criteria are:

- Speed: Is early completion of the project required?
- Certainty of time: Is it important for the project to be completed on time?
- Certainty of cost: Is a firm price needed before any commitment to start the construction is given?
- Price competition: Is the selection of the construction team on the basis of price competition important?
- Flexibility: Are variations/changes necessary after construction has started?
- Complexity: Is the proposed building highly specialised, technologically advanced or highly serviced?
- Quality: Is high quality of the project, in design, material or workmanship, important?
- Responsibility: Is liability for the design by the contractor in favour?
- Risk allocation: Is the transfer of the risk of cost and time slippage form the client to the contractor important?

It is up to the client to rank these criteria in order of importance for their specific project by assigning a certain ranking and trade of position to these criteria in the procurement strategy.

Throughout the years various follow up studies added different aspects to this NEDO report (Naoum & Egbu, 2018). Criteria were added to the nine NEDO project criteria, new topics such as the client characteristics and the external environment were added and the link between criteria and procurement strategies was investigated.

The decision for a certain type of procurement method has increased in complexity over the years. Reasons for this are the developing technical complexity of projects and the growth in procurement methods available. It is stated that the 'classic criteria' such as those from the NEDO documents can no longer be solely used for current projects (Luu, Thomas Ng, & Chen, 2003). Current projects are more complicated than those in the days of the NEDO documents. Furthermore, criteria are hardly ever totally mutually exclusive. Potential pitfalls lie ahead when combining this with the uniqueness of every project or client. Besides, over time some changes concerning the criteria and their weighting have occurred due to new technologies, innovations and society (Naoum & Egbu, 2018).

A couple of follow up studies used the nine NEDO criteria while other studies stated that more topics influence the procurement too. Therefore, the client characteristics (Moshini & Botros, 1990), the project characteristics (Ambrose & Tucker, 2000) and the external environment (Alhazmi & McCaffer, 2000) need to be considered as well.

### 2.2.1 Client characteristics

One of the first items to be added was the fact that the client in itself is part of the project. Therefore, client characteristics should be taken into account when considering the characteristics that influence the selection of the procurement strategy. Different studies looked at the categorisation of clients, followed by investigating the needs of the client in relation to their selection of procurement systems (Masterman & Gameson, 1994); (Naoum & Mustapha, 1994); (Luu, Thomas Ng, & Chen, 2003); (Nahapiet & Nahapiet, 2006). This is done by classifying clients in different categories (Masterman & Gameson, 1994). The first classification that is made is whether the client is a primary or a secondary constructor. This means that for a primary constructor the main business model is to build buildings and make a profit by selling or renting them out. While a secondary constructor might have experience with building but they are not familiar with this sort of building or it is not their business model to make a profit out of real estate. The other classification that is made is the level of experience (Nahapiet & Nahapiet, 2006). There are experienced and inexperienced clients. These classifications make four different types of theoretical clients:

- Secondary inexperienced
- Secondary experienced
- Primary inexperienced
- Primary experienced

For the secondary inexperienced client the relationship usually is a client-professional relation, meaning that clients are very much influenced by their first contact with the building industry. This first contact with the industry is often arbitrarily made and from this point of contact on the client very much relies on the advice of the professional. Furthermore, there is still a gap in the industry's attempt to educate the inexperienced client (Moore, 1985). Therefore, the contractor has a lot of influence in the process and outcome of the projects of secondary inexperienced client. It came forward that the more experienced the designer was, the more the client was satisfied with the building time and the quality (Naoum & Mustapha, 1994).

The secondary experienced client on the other hand does have experience with relevant projects and therefore might be able to arrange a well considered contact with the building industry or can have some established contacts with (preferred) contractors (Masterman & Gameson, 1994). These clients are for instance multinationals that have the same type of building in a lot of places. These clients have in-house expertise concerning this type of building. When these clients are faced with a totally different building project than they are used to, it is important that they know their limitations. It might be an advantage for these clients to be familiar with building projects and have good contact with contractors. They still have to be careful not to adopt an identical approach for this new type of project. Which is defined as 'habituation' (Bresnan & Haslam, 1991).

The primary inexperienced client is a type of client that is very unlikely to exist (Masterman & Gameson, 1994). This is because it is very unlikely that a company or person who's primary income comes from constructing buildings does not have any relevant experience or expertise.

Last but not least, the primary experienced client is generally financially well equipped and has in-house professionals or has the ability to employ professionals with experience in construction projects to represent them and look after their interests. This type of client can induce changes in a way that eventually effects the entire construction sector. Pension funds and insurance companies are typical examples of these institutional investors.

In general the experienced clients were more satisfied than the other ones, a reason for this is the amount of in-house expertise. Besides, a higher degree of in-house expertise resulted in a better control of time and cost. Due to their in-house expertise, the experienced clients were in a better position to evaluate the success of the project. It turned out that clear communication is key to project success. Thereby, the designer has a great impact in turning the clients wishes into unambiguous demands for the contractor (Naoum & Mustapha, 1994). Furthermore, there is a difference between public and private clients. Public sector contracts were constructed more slowly than those in the private sector and the public sector was less satisfied with the final quality of the building. A logical explanation for this is the fact that the public sector puts more emphasis on the lowest price, while private clients are often more concerned with the construction time and place more emphasis in certainty of cost rather than the lowest cost (Naoum & Mustapha, 1994). Furthermore, clients may have unrealistic desires concerning the project criteria. In order to avoid disappointment, it is important that clients are aware of their performance requirements and the feasibility of them. It is acknowledged that the objectives of cost, time and quality (Atkinson, 1999) are interrelated and conflicting and that it is challenging to achieve all of them. Slack to a certain percent must be allowable and clients need to weigh each of the criteria for every single project (Walker, 2015).

The following needs appear to be most important to the average client when choosing the appropriate procurement system for their project (Naoum & Mustapha, 1994):

- a need to be kept informed and be actively involved at all stages of the project
- a need for certainty of the final cost
- a need for certainty of the day for completion
- a need to achieve value for money
- a need to obtain the lowest possible tender

### 2.2.2 Other characteristics

Other characteristics that were studied, besides the project characteristics and client characteristics, are the external environment (Alhazmi & McCaffer, 2000), the risks (Luu, Thomas Ng, & Chen, 2003), the distribution of the risks (De Koning & Sproncken, 2001) and complexity (Designing buildings, 2016); (Love, Edwards, Irani, & Sharif, 2012); (Luu, Thomas Ng, & Chen, 2005); (Samuel George & Egbu, 2016); (Luu, Thomas Ng, & Chen, 2003).

### External environment

Different methods were used to discover which criteria to take into account for the procurement strategy. Methods that were used to study this are a postal questionnaire survey (Luu, Thomas Ng, & Chen, 2003), by doing interviews (Naoum & Mustapha, 1994) and case investigations (Nahapiet & Nahapiet, 2006).

The postal questionnaire survey encompassed a total of 34 criteria regarding project requirements, client characteristics and the external environment investigating the industries views' concerning the relationship between criteria and procurement strategy (Luu, Thomas Ng, & Chen, 2003). The respondents for the questionnaire, client and project managers, were asked to rate the level of influence of the 34 criteria through a six-point Likert scale. Due to the responses from the clients and the project managers, 3 criteria were rearranged with other criteria and 6 criteria were excluded since neither of the groups of respondents found them of much influence. Due to the manner in which the information is stated in the article it is not possible to track down the ranking of the final 25 criteria, therefore the ranking of the 28 criteria, before combining 6 criteria, is shown here and in Appendix A.

The ranking of the 28 criteria is as follows:
1. Client's requirement for within budget completion
2. Client's requirement for on-time completion
3. Client's requirement for value for money
4. Project type
5. Project size
6. Market's competitiveness
7. Client's willingness to take risks
8. Availability of experienced contractor
9. Client's trust towards other parties
10. Known site factors likely to cause problems
11. Technology feasibility
12. Client's experience
13. Client's willingness to be involved
14. Client's in-house technical capability
15. Building construction type
16. Client type
17. Client's requirement for low operational cost
18. Client's requirement for low maintenance cost
19. Client's financial capability[1]
20. Client's requirement for highly serviced or technically advanced building
21. Regulatory feasibility
22. Materials availability
23. Unknown site risk factors
24. Client's requirement for aesthetic building
25. Political constrains
26. Industrial actions
27. Usage of pioneering technology
28. Labour productivity

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[1] Criteria 18 and 19 have the same ranking (18) in the article 'Parameters governing the selection of procurement system' (Luu, Thomas Ng, & Chen, 2003).

The following criteria are combined. *14 client's in-house technical capability* and *18 client's financial capability* are now *client's in-house capability*. *23 unknown site risk factors* and *10 known site risk factors likely to cause problems* are now *site risk factors*. Lastly, *6 market's competitiveness* and *8 availability of experienced contractor* are combined to *market competitiveness and contractor's availability*. This resulted in a list of 25 criteria. These 25 criteria were categorized in eight distinct factors. Table 1 shows which criteria belong to which factor.

| No. | Factor | Associated variables |
|---|---|---|
| 1 | External environment | Regulatory feasibility |
| | | Materials availability |
| | | Technology feasibility |
| | | Labour productivity |
| | | Market's competitiveness and contractor's availability |
| 2 | Project risks | Industrial actions |
| | | Political constraints |
| | | Site risks factors |
| | | Usage of pioneering technology |
| 3 | Client's long-term objectives | Client's requirement for low operational cost |
| | | Client's requirement for low maintenance cost |
| 4 | Project characteristics | Project type |
| | | Project size |
| | | Building construction type |
| 5 | Client's short-term objectives | Client's requirement for within-budget completion |
| | | Client's requirement for on-time completion |
| | | Client's requirement for value for money |
| 6 | Client's characteristics | Client's in-house capability |
| | | Client's experience |
| | | Client type |
| 7 | Client's involvement and risk allocation | Client's willingness to be involved |
| | | Client's trust towards other parties |
| | | Client's willingness to take risks |
| 8 | Building's aesthetics and complexity | Client's requirement for aesthetic building |
| | | Client's requirement for advanced building |

Table 1 PSPs and factors (Luu, Thomas Ng, & Chen, 2003)

From these eight factors the factors *external environment* and *project risks* had the highest communality. Indicating the strong relation that exist between the criteria within these factors. Which means that when selecting a procurement system, much attention should be given to the parameters within the first and second factor in order to make a wise decision (Luu, Thomas Ng, & Chen, 2003).

The interviews and case investigations presented the following factors: designer characteristics, contract procedure, procurement method and project performance (Naoum & Mustapha, 1994). The performance level required by the client encompasses high requirements concerning the speed and/or cost of the project, meaning that the project doesn't have slack when it comes to these requirements. This does not mean that other projects don't require high performance, they just don't have high requirements concerning the cost or building time as a major driver of the project. It became clear that the projects with high performance requirements concerning time or cost are preferably executed with a non-traditional contract (Nahapiet & Nahapiet, 2006).

## Risks

Risks in building projects are generally seen as a possible occurring event which has a negative effect on the project. The transfer of all the risks to one single organisation is possible in theory (Luu, Thomas Ng, & Chen, 2003). However, the risks involved with a building project cannot be regarded separate from the organisation of the building project. It is important to clarify the risks and appoint them, both contractual and functional. Ambiguity in the distribution of risks will lead to cost increases due to risk allowances. It can be a natural habit of one party to appoint another party for the risks, which might not be an ideal situation (De Koning & Sproncken, 2001). The most important risks associated with a building project relate to quality, costs, time and the external environment. These risks can be categorized accordingly:

1. Integration of design and construction
2. Possibility for alterations
3. The certainty that agreed contractual remedies can be implemented
4. Shortening the lead time of preparation and execution
5. Price certainty at an early stage

## Complexity

In different studies the level of complexity of the projects turned out to be an important factor (Hertogh & Westerveld, 2010); (Nahapiet & Nahapiet, 2006); (Luu, Thomas Ng, & Chen, 2003). In a study by Nahapiet & Nahapiet (2006) projects were classified according to two variables, the first variable is the performance requirements and the second variable is the relative construction complexity. Two projects were classified high on both scales and these projects were both managed by contractual arrangements in order to reduce the number of organisations involved in the project. The first project had a design-build contract in order to have one firm responsible for the entire project. The other project had a multidisciplinary design team responsible for the project. In both projects the contractual arrangements were selected carefully in order to ease coordination. Meaning that complex projects with high performance requirements need to be managed in a way that facilitates simultaneous consideration of all the interrelated aspects of the project. The projects that had high performance requirements concerning speed or low cost all stated that contractual arrangements are amongst the important factors of letting the project become a success.

### 2.2.3 The link between criteria and procurement strategies

Several studies have tried to establish a link between different criteria and procurement strategies (Skitmore & Marsden, 1988); (Cheung, Lam, Leung, & Wan, 2001); (Luu, Thomas Ng, & Chen, 2003); (Luu, Thomas Ng, & Chen, 2005); (Love, Edwards, Irani, & Sharif, 2012); (Naoum & Egbu, 2018). Methods that are used for establishing this link are a multi-attribute approach and an analytical hierarchy process (Naoum & Egbu, 2018). In these methods experts set a utility factor (weighting factor) per criteria per procurement strategies. The user of the model must indicate a relative importance (priority rating) for each criterion on a preset scale. Then these priority ratings are rationalized (dividing each of the priority ratings by the sum of all the ratings). These priority ratings are then entered in the table and multiplied by the associated utility factor. Finally, the result per procurement path is calculated and ranked from high to low. The most appropriate procurement method has the highest total result (Skitmore & Marsden, 1988) (Cheung, Lam, Leung, & Wan, 2001) (Naoum & Egbu, 2018).

This is illustrated with an example from the article 'An analytical hierarchy process based procurement selection' by Cheung, Lam, Leung, & Wan from (2001). Eight criteria were taken into account and five project managers assigned the mean utility values for each criterion for the six different procurement strategies. The results can be seen in table 2:

| Procurement selection criteria | Procurement strategies[a] | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| Speed | 50.0 | 67.3 | 94.6 | 90.4 | 71.9 | 72.7 |
| Certainty | 80.0 | 74.6 | 76.2 | 67.7 | 55.0 | 62.7 |
| Flexibility | 48.8 | 50.0 | 56.5 | 52.7 | 74.6 | 66.9 |
| Quality level | 81.9 | 73.8 | 62.3 | 61.9 | 68.1 | 65.4 |
| Complexity | 64.6 | 60.8 | 66.2 | 76.5 | 87.3 | 88.5 |
| Risk avoidance | 78.5 | 66.2 | 72.7 | 68.5 | 70.8 | 71.9 |
| Price competition | 89.2 | 84.8 | 61.9 | 63.8 | 67.7 | 50.4 |
| Point of responsibility | 82.3 | 78.6 | 68.1 | 66.9 | 71.2 | 68.8 |

[a]Key: A, sequential traditional; B, accelerated traditional; C, competitive design & build; D, turnkey package; E, management contracting; and F, construction management

**Table 2 Mean utility values of procurement selection criteria for procurement strategies (Cheung, Lam, Leung, & Wan, 2001)**

Not surprisingly, the criteria speed had a high utility score for the procurement methods Design & Build and Turnkey, due to the possible time overlap of the design and build phase, while sequential traditional had the highest utility score for cost certainty. Traditional approaches where first the design is made followed by the building phase generally guarantee the quality and price competition. Furthermore, the criteria of flexibility scores relative low for most of the procurement methods except management contracting and to a lesser extent construction management. This can be explained by the fact that the owner is most involved in the management contracting method when compared with the other procurement methods.

Next, the analytical hierarchy process lets the client compare between two criteria, to decide which one is most important. The client emphasizes what he considers important for his project. This way the client and the project characteristics find their way into the model. A risk averse client can put more focus on certainty while another client can put more focus on speed. Different project characteristics can be dealt with via these important weightings. This can be seen in table 3**Fout! Verwijzingsbron niet gevonden.**.

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | Two criteria are of equal importance |
| 3 | Weak importance of one over another | Experience and judgement slightly favour one criterion over another |
| 5 | Essential and strong importance | Experience and judgement strongly favour one criterion over another |
| 7 | Very strong and demonstrated importance | A criterion is strongly more important than the other |
| 9 | Absolute importance | The evidence favouring one criterion over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values between adjacent scale values | When compromise is needed |
| Reciprocals of above nonzero | If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i | A reasonable assumption |

Example: If Speed is very strongly more important than Certainty, then the rating assignment in the matrix should appear as:

| Criteria/Criteria | Speed | Certainty | Flexibility | Quality level | Complexity | Risk avoidance | Price competition | Responsibility |
|---|---|---|---|---|---|---|---|---|
| Speed | 1 | 7 | | | | | | |
| Certainty | | 1 | | | | | | |
| Flexibility | | | 1 | | | | | |
| Quality level | | | | 1 | | | | |
| Complexity | | | | | 1 | | | |
| Risk avoidance | | | | | | 1 | | |
| Price competition | | | | | | | 1 | |
| Responsibility | | | | | | | | 1 |

**Table 3 AHP pair wise comparison matrix for procurement selection criteria (Cheung, Lam, Leung, & Wan, 2001)**

For example, in the second row, the client needs to compare speed with certainty, followed by comparing speed with flexibility. Thus, when speed is considered more important compared to certainty, a number 7 is inserted in the table. Consistency in the comparison matrix is important. If, for example, speed is twice as important as certainty and certainty is three times more important than flexibility, then speed is six times as important as flexibility. The proposed method for using this model is by letting the decision-maker fill in the comparison matrix (table 3). An example of a trial run with the model is shown in table 4.

| Criteria | Importance weightings (from AHP) | A Sequential traditional | | B Accelerated traditional | | C Competitive D & B | | D Turnkey | | E Management contracting | | F Construction management | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Utility | Result | Utility | Result | Utility | Result | Utility | Result | Utility | Result | Utility | Result |
| Speed | 0.159 | 50 | 7.95 | 67.3 | 10.7007 | 94.6 | 15.0414 | 90.4 | 14.3736 | 71.9 | 11.4321 | 72.7 | 11.5593 |
| Certainty | 0.219 | 80 | 17.52 | 74.6 | 16.3374 | 76.2 | 16.6878 | 67.7 | 14.8263 | 55 | 12.045 | 62.7 | 13.7313 |
| Flexibility | 0.034 | 48.8 | 1.6592 | 50 | 1.7 | 56.5 | 1.921 | 52.7 | 1.7918 | 74.6 | 2.5364 | 66.9 | 2.2746 |
| Quality | 0.126 | 81.9 | 10.3194 | 73.8 | 9.2988 | 62.3 | 7.8498 | 61.9 | 7.7994 | 68.1 | 8.5806 | 65.4 | 8.2404 |
| Complexity | 0.061 | 64.6 | 3.9406 | 60.8 | 3.7088 | 66.2 | 4.0382 | 76.5 | 4.6665 | 87.3 | 5.3253 | 88.5 | 5.3985 |
| Risk Avoidance | 0.233 | 78.5 | 18.2905 | 66.2 | 15.4246 | 72.7 | 16.9391 | 68.1 | 15.8673 | 70.8 | 16.4964 | 71.9 | 16.7527 |
| Price Competition | 0.116 | 89.2 | 10.3472 | 84.8 | 9.8368 | 61.9 | 7.1804 | 63.8 | 7.4008 | 67.7 | 7.8532 | 50.4 | 5.8464 |
| Responsibility | 0.051 | 82.3 | 4.1973 | 78.6 | 4.0086 | 68.1 | 3.4731 | 66.9 | 3.4119 | 71.2 | 3.6312 | 68.8 | 3.5088 |
| Total | 0.999 | | 74.2242 | | 71.0157 | | 73.1308 | | 70.1376 | | 67.9002 | | 67.312 |
| Ranking order | | | 1 | | 3 | | 2 | | 4 | | 5 | | 6 |

**Table 4 Procurement strategy decision chart for respondent no. 1 (Cheung, Lam, Leung, & Wan, 2001)**

The procurement strategy with the highest total score is the procurement that best matches the client and project characteristics. This process is aimed at developing a selection method that enhances the objectivity. This way the decision for a procurement strategy can be based on a calculation (Mulder, 2017).

Another method that was investigated for linking criteria to procurement strategies is case-based reasoning (CBR), a method that solves new problems by adapting the solutions that were used for old problems (Luu, Thomas Ng, & Chen, 2005). These old solutions can be adapted to suit the current situation. Current practice is to first identify the procurement selection criteria and after that make a procurement decision based on these criteria. The selection of criteria will vary for different projects, based on the characteristics of the project, the client and the external environment. After the criteria are formulated the procurement method is selected. Generally a weighting is assigned to each criterion and the procurement system that best matches these criteria is the one that is going to be used. This method looks at previous projects and investigates how the procurement was done in projects with similar criteria and similar weightings. This can give insight in what went well or wrong in those projects. These previous procurement systems can be adjusted in order to suit this particular project best. In order to compare all these previous procurement systems a data base should be available. This can be done with a case-based procurement selection model. This model consists out of four parts: input, criteria, selection and output modules. In the input module the user enters data, such as the characteristics of the project, the client and the environment. This is the input for the criteria-module. This criteria-module creates a list of criteria and assigns a weighting for each criterion. This list is then used to select a case from the database with a similar list of criteria. Then, the output module will provide cases that match the list of criteria. The user can compare this case with its current project and verify how the procurement method that was used in the case was successful or not and whether he can adopt it or should adjust it in order to adopt it. Finally, the current project can be added to the database with its list of criteria and how successful it turned out (Luu, Thomas Ng, & Chen, 2005).

### 2.2.4 Side notes

Research has proved that the procurement method can be of important influence on the project performance, but it is not the only factor influencing it (Naoum & Mustapha, 1994). This has led to the development of various procurement selection models and methods, as can be seen in the above mentioned literature. Most of these approaches help in rationalizing the procurement selection decision but fail to address the implicit interrelationships that exist between the procurement selection criteria (Luu, Thomas Ng, & Chen, 2005). Furthermore, there is a consensus that one procurement method is better than all others for an individual project but that no one procurement method is better than others for any project (Love, Skitmore, & Earl, 1998). The most appropriate procurement method depends on the type of client, his needs and the project with its specific circumstances (Masterman & Gameson, 1994). Team integration seems to be key in order to achieve a successful project (Naoum & Egbu, 2018). The conclusion of a study into the factors affecting the procurement selection was that no mutually exclusive sets of criteria can completely determine an appropriate procurement strategy for a specific project (Ireland, 1985). It is good to keep this reference in mind when setting up a model. There might be something peculiar to a project which is too unique to capture in a model. Besides, the statement of 'no mutually exclusive sets of criteria' means that there is a correlation or dependence between certain criteria. This must be taken into account for the characteristics of the model.

## 2.3 Conclusion from literature

The literature shows how the process of thinking about procurement started and evolved throughout the years. Starting to think upon criteria related to the project characteristics, later on including client characteristics and the external environment as well. For clarity and unambiguity all characteristics and criteria will be referred to as criteria hereafter. The overarching topics such as the external environment and the client characteristics are called main headings.

Several criteria are present in multiple articles, as can be seen in appendix A. The criteria in appendix A are grouped under main headings. For instance all the criteria that have something to do with the building time or delivery date are grouped under the main heading of time and are given the same background colour for convenience. The main headings that are of influence according to the literature are:

- Time
- Cost
- Quality
- Flexibility
- Risk (allocation/responsibility)
- Complexity
- Innovation
- Modern concepts/tools
- Cost during the usage phase
- Involvement of the client
- Relational
- External environment
- Client characteristics

Most of the literature captures these main headings, but the specific criteria can be somewhat different or formulated differently per article. This can be seen in table 5, presented on the next page, and in appendix A. As for the client characteristics, the literature is quite uniform in the criteria that are influential. Whether or not the client has experience with similar types of projects and whether it is the core business of the client to develop projects.

The literature study is the starting point for the interviews. The interviews function as a validation of the literature study. It might be that some criteria from the literature are not present in the daily practice or the other way around, that the literature is not completely comprehensive. The interviews function as a validation and addition to the literature and together they form the input for the initial model.

| Main heading | Criteria | literature | NEDO | Which procurement system | Client characteristics and needs in relation to their selection of building procurement systems | Influence of the client, designer and procurement methods on project performance | An analytical hierarchy process based procurement selection method | Parameters governing the selection of procurement method | Formulating procurement selection criteria through case-based reasoning approach (general criteria are mentioned, extra criteria that are project bounded should be | A comparison of contractual arrangements for building projects | Participatory action research approach to public sector procurement selection (=NEDO CRITERIA MET WEGINGSFACTOR) | Modern selection criteria for procurement methods | Contractering bij bouwprojecten | Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria (included for comparison with the investigated articles) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | author | | NEDO | Skitmore R.M. & Marsden C | J.W.E. Masterman & R.N. Gameson | S.G. Naoum & F.H. Mustapha | cheung, s., lam, t., leung, m. | Duc Thanh Luu, S. Thomas | Duc Thanh Luu, S. Thomas Ng, See E | Nahapiet & Nahapiet | Love, P., edwards, d., irani, z. and Shamil | George Naoum an | Hans de Koning and Vili Sproncken | R. Atkinson |
| | year | | 1985 | 1988 | 1994 | 1994 | 2001 | 2003 | 2005 | 2006 | 2012 | 2015 | 2001 | 19 |
| Time | Time | | | | | Total time (design + build time) | | | | | | | | x |
| | Speed (early completion) | | x | 1 | | | x | | | x | x | x | x | |
| | Time certainty | | x | | x | | | | x | x | x | x | x | |
| | On-time completion | | | | | | | 2 | x | | | | | |
| | Pre-construction time | | | | | x | | | | | | | | |
| | Time overrun | | | | | x | | | | | | | | |
| | Client satisfaction on time | | | | | x | | | | | | | | |
| Cost | Cost | | | | | | | | | | | | | x |
| | Cost certainty | | x | | x | | x | | x | | x | x | x | x |
| | Price competition | | x | 4 | x | | x | | x | | x | x | x | |
| | Tight cost | | | | | | | | | x | | | | |
| | Within budget completion | | | | | | | 1 | x | | | | | |
| | Unit cost | | | | | x | | | | | | | | |
| | Cost overrun | | | | | x | | | | | | | | |
| | Certainty (over time and cost) | | | 2 | | | | 3 | | | | | | |
| | Value for money | | | | x | | | | | | | | | |
| Quality | Quality of the end product | | x | | | | x | | x | | x | x | x | x |
| | Quality of the process | | | 5 | | | | | x | | | x | | x |
| Flexibility | Flexibility | | x | 6 | | | | | x | | | x | | |
| | Possible flexibility and variations | | | | | | x | | | x | x | x | x | |
| Risk (allocation/responsibil | Risk avoidance and responsibility | | | 3 | | | x | | | | | | | |
| | Risk allocation | | x | | | | | | x | | x | x | x | |
| | Clients willingness to take risks | | | | | | | 7 | x | | | | | |
| | Level of risk to the clients | | | | | | | | x | | | x | | |
| | Responsibility | | x | | | | | | x | | x | x | x | |
| | Clear division of roles and responsibilities | | | | | | x | | x | | | x | | |
| | Unknown site risk factors | | | | | | | 23 | | | | | | |
| | Known site factors likely to cause problems | | | | | | | 10 | x | | | | | |
| | Safety issues | | | | | | | | | | | x | | |
| Complexity | Building complexity | | | 7 | | | | | | | | | | |
| | Complexity, the suitability of the procurement method in handling complex projects | | | | | | x | | | | | | | |
| | Complexity | | x | | | | | | x | | x | x | | |
| | Size of project | | | | | | | 5 | x | | | x | | |
| | Project type | | | | | | | 4 | x | | | | | |
| | Building construction type | | | | | | | 15 | x | | | | | |
| Innovation | Project requirements | | | | | | | | | | x | | | |
| | Need for buildability | | | | | | | | | | | x | | |
| | Need for creativity and innovation in the design | | | | | | | | | | | x | | |
| | Importance of sustainability in design and material | | | | | | | | | | | x | | |
| | Highly serviced or technically advanced building | | | | | | | 20 | x | | | | | |
| | Clients requirement for aesthetic building | | | | | | | 24 | x | | | | | |
| | Usage of pionering technology | | | | | | | 27 | | | | | | |
| Modern concepts/tools | Importance of utilizing the supply chain concept | | | | | | | | | | | x | | |
| | Facilitating lean construction | | | | | | | | | | | x | | |
| | Application of value engineering | | | | | | | | | | | x | | |
| | Need for the application of BIM | | | | | | | | | | | x | | |
| | Need for e-procurement | | | | | | | | | | | x | | |
| Cost during the usage phas | Importance of operating and maintenance costs | | | | | | | | | | | x | | |
| | Low maintenance cost | | | | | | | 18 | | | | | | |
| | Low operational cost | | | | | | | 17 | | | | | | |
| Involvement of the client | Kept informed and actively involved at all stages of the project | | | | x | | | | | | | | | |
| | Clients willingness to be involved | | | | | | | 13 | x | | | | | |
| Relational | Contractual relations and legal relations between parties | | | | | | | | | | | | | |
| | Functional relations between parties | | | | | | | | | x | | | x | |
| | Phasing of the building process and the time of participation of parties | | | | | | | | | x | | | x | |
| | External environment factors | | | | | | | | | | | | | |
| External environment | Technology feasibility | | | | | | | 11 | | | | | | |
| | Regulatory feasibility | | | | | | | 21 | | | | | | |
| | Materials availability | | | | | | | 22 | | | | | | |
| | Availability of experienced contractor | | | | | | | 8 | x | | | | | |
| | Labour productivity | | | | | | | 28 | | | | | | |
| | Industrial actions | | | | | | | 26 | | | | | | |
| | Markets competitiveness | | | | | | | 6 | x | | | | | |
| | Political constrains | | | | | | | 25 | | | | | | |
| | Stakeholders | | | | | | | | | | | | | |
| | Bestemmingsplan | | | | | | | | | | | | | |
| | Client characteristics | | | | | | | | | | | | | |
| Client characteristics | Client characteristics in literatuur | | | | Indeling secondary of primary developer in experienced/inexperienced | Client indeling op blz 222 Experience of the building team with the building proces has significantly influenced the time and cost overruns, as well as the quality standard of the project. | | | | | | | | |
| | Clients experience | | | | x | | | 12 | x | x | | | | |
| | Client type (primary/secondary) | | | | x | | | 16 | x | x | | | | |
| | Clients trust towards other parties | | | | | | | 9 | | | | | | |
| | Clients financial capability | | | | | | | 19 | | | | | | |
| | Clients in-house technical capabilities | | | | | | | 14 | x | x | | | | |

Table 5 Overview of the different criteria (and their ranking when provided) per article.

# 3. Interviews

Besides searching and processing the literature, interviews are performed with experts in the field. The results of these interviews are explained in this chapter, the full interviews can be found in the appendices.

## 3.1 Introduction to the interviews

In order to enrich the literature study, interviews were performed with experts from the field. The reason for these interviews is twofold: the interviews serve as a check for the literature and they can provide additional insights which are not captured in the literature. First the questions for the interviews are introduced, followed by the interviewees, then a summary of the interviews is given followed by the conclusion of the interviews. All the interviews are included in the appendices. The next chapter explains how the literature and interviews serve as input for the procurement model.

## 3.2 The interviews

The goal of the interviews is to get information concerning the decision for a type of contract. In order to get this information questions such as the following are prepared:

- When you are going to tender a project, what do you pay attention to? Do you use criteria or certain parameters that influence the choice of contract?
- Is it useful if a client puts purely functional requirements on the market, or a complete written-out specification. What is the most important difference between these two?
- If an integrated contract is chosen, on what factors is that decision based?
- Which factors influence traditional contracts to meet the requirements and objectives?
- Are the different factors related?
- What is a decisive factor in choosing between a traditional or an integrated contract in the case of a movable bridge project?
- If you have to focus on criteria such as budget, time, quality and complexity, what is a determining factor for a contract?

Questions like these are asked in the interviews to get the viewpoint of professionals concerning the daily practice when choosing a type of contract. The interviews with experts from the field encompassed clients and contractors/suppliers or people acting on behalf of them. Three interviews were performed with consultants acting on behalf of a client or contractor. These interviewees work and/or represent clients and contractors on a daily business. They were the first to be interviewed and this functioned partly as a rehearsal for the other interviews. Since two out of these three rehearsal interviews were seen as reputable, they are included in the appendices too.

### 3.2.1 Contractors

On the contractor side two interviews were performed at different companies. These interviewees were interested in being interviewed concerning the contracting strategy and all aspects influencing this decision. It is interesting to get to know their viewpoint, because in integrated contracts the contractor can introduce or brisk up innovation in a project. A company can get involved in early stages of a project when innovation plays a role or when an integrated contract is used. During these interviews the focus was on explaining the viewpoint of a contractor.

### 3.2.2 Clients

On the client side four interviews were performed at (semi) governmental bodies. Three interviewees were involved in the purchasing department and one was involved in the engineering division. Furthermore, three of the interviews are or were involved in the procurement of moveable bridges. Two interviewees worked on the same moveable bridge project. This moveable bridge project is a project of three clients who all have a stake in the project. One client will be the owner of the ramps, another will be the owner of the moveable part of the bridge and the third client will exploit the infrastructure over the bridge. Since previous procurements were not successful the three clients, all governmental bodies, decided to internally hire the expertise from the engineering division of one of the clients. One of the interviewees is part of the engineering division and explained how they came to a procurement strategy. A procurement strategy that finally got the project starting after many years of delay and lawsuits. While the other interviewee explained the difficulties during the previous procurements.

In addition, it was explained how governmental bodies deal with procuring new bridges and renovation of bridges. Especially renovation is important because of all the bridges currently present. There are a lot of considerations to take into account when procuring a renovation project, especially when dealing with monumental bridges and surroundings.

Furthermore, some interviewees explained the transition that the organisation went through in order to come to the current way of procuring. A transition from only procuring in a traditional manner to nowadays being able to also procure in an integrated manner. All in all, an interesting insight in the dynamics of procuring on the level of a (semi) governmental bodies.

### 3.2.3 Consultants acting on behalf of a client

The two interviews with people acting on behalf of a client partly functioned as a rehearsal for the other interviews. The more neutral viewpoint of these interviewees, when compared with the interviewees with the clients and the contractors, resulted in a more unbiased position. This nuanced viewpoint, positioned in between the viewpoints of the client and the contractor, was insightful.

## 3.3 Summary of the interviews

Interviewee 1 explained that there have been some changes in the manner of contracting. Through the years the focus shifted from technical based to more soft factors for the procurement. Important parts of the interview concern the communication and the client characteristics. Quality, as stated at the start of the project can be reached if client and contractor understand each other well, and if the client doesn't change the specifications of the project when the project is being undertaken. Furthermore, the quality of the contract and the knowledge and experience of the client are of influence and communication is the key to success according to interviewee 1.

During the interview with interviewee 2 it became clear that on the contractor side, team effort and clear communication are vital elements for successful projects. Team efforts in the sense that the contractors or subcontractors all know what the main goal of the project is and why something needs to be done in a specific manner or a specific moment. It is the complete opposite of each party pursuing its own goals. This is in line with clear communication, the contractors and the client need to be fully aware of all the items related with the project. Why the client wants something done or to be done before a certain moment. According to interviewee 2 it is a pitfall that contractors think they understand what the client wants and immediately want to start working. While in general they partly understand what the client precisely wants. Clear communication ensures that contractors indeed build what the client has in mind.

From the interview with interviewee 3 it became clear that the organisation of the client needs to be composed in such a manner that different procurement methods can be used. The organisation of the interviewee was still dealing with a culture where traditional procuring through writing specifications was seen as the standard method, unless an explanation showed why a different strategy must be used. Instead of seeking the optimal method for every project. The interviewee explained that even the title of functions were in line with the traditional strategy, the whole culture was aimed at traditional procuring. This makes it hard to accept another procurement method since staff members need to fulfil a completely other role in integrated contracts, from prescribing everything in detail to performing functional checks. Furthermore, the external environment can be a big influence on the project. Interviewee 3 gave multiple examples of projects that were adjusted or put on hold due to the influence of stakeholders. In case of a moveable bridge on which he worked it resulted in a law suit and thereby a complete hold of the design and years of delay for the whole project.

Interviewee 4 highlighted very much that the method of procurement depends on the project characteristics and the external environment. For the project, on which he worked, there was no space for innovative or alternative designs by contractors. Furthermore, the zoning plan was very detailed and stringent. Due to these circumstances there was no room for the market to come up with solutions other than regulated in the zoning plan. Furthermore, stakeholders were very much involved in the project which even resulted in a law suit. That is why eventually the decision was made to create the design and let contractors tender on price in combination with requirements concerning the surrounding. This shows that it is really important to know if there is a potential benefit to be gained by letting the market come up with a design or that it is just causing problems to transfer the design to a contractor.

The interview with interviewee 5 showed the importance of innovation, the external environment and the clients organisation. Innovation can be a good thing for a project, however its technology must be proven. As a client you do not want to end up with a bridge that is not working as specified because it is the first one of its kind. Furthermore, the external environment is very important, especially in a densely populated area you need to plan your project in such a way that it minimizes the nuisance for the surroundings. Besides, if you are working on the renovation of a monumental bridge, a lot of extra requirements need to be clear for the contractor. As for the client's organisation the new project or renovation project must fit in the portfolio of other assets. If there is a maintenance contract for all the bridges in their domain, then it is less likely that the client will put just one bridge as a DBM project in the market. The client organisation also deals with the topic that interviewee 3 explained. The client organisation must be fit for a specific type of contract. For instance, is staff able to recognize the value represented by each plan or design submitted by a contractor. Can staff prescribe a functional basis and are they able to check all sort of plans that the contractor comes up with. Thus the client's organisation must be able to fulfil the proper roles that accomplish a procurement strategy. This is the same for contractors, as a client you can come up with a perfect contract, but if there are no contractors that are able to match it then you are still not procuring in an optimal manner.

Interviewee 6 also mentioned the client organisation as a factor that has great influence in the type of contract. The interviewee explained the cultural transition that the organisation went through in order to be able to procure in a modern manner. The procurement method they use is Performance Based Maintenance at which pre-qualified contractors are allowed to bid. With the Performance Based Maintenance contracts a contractor is liable for the maintenance of the infrastructure for several years. The infrastructure must be in line with the prescription in the contract. It us up to the contractor to decide if maintenance is needed and what sort of maintenance or renewal must be done.

Interviewee 7 emphasized the tension that can be present between a client and the contractor. Reasons for this tension are the competition on price, the competitiveness of the market and the differences in interpretation of what is meant in the requirements. By referring to norms and standards the differences in interpretation can be reduced. Furthermore, the interviewee emphasized that eliminating the differences in interpretation by referring to facts, norms and standards fosters the collaboration. However, eliminating these differences can be challenging due to the different interests of the client and the contractor.

Interviewee 8 mentioned that, as a contractor, you prefer that references are made to building codes and norms. You can show to the client that you have build according to the building code. This prevents problems from arising when the project is transferred from contractor to client. Besides, when you are building according to building codes you can always assure that you were not negligent in case defects occur after the transfer of the project. Furthermore, the benefits and pitfalls in certain types of contracts were emphasized.

An overview of all the criteria per interview is given in table 6.

| | A | B | C Criteria from interview | D Interview 1 | E Interview 2 | F Interview 3 | G Interview 4 | H Interview 5 | I Interview 6 | J Interview 7 | K Interview 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Main heading | Criteria | | | | | | | | | |
| 4 | Time | Time | | x | x | x | | | Time pressure on tenders | | x |
| 5 | | Speed (early completion) | | | | | x | | | | |
| 6 | | Time certainty | | | x | | | | | | |
| 7 | | On-time completion | | | | x | x | | | x | |
| 8 | | Pre-construction time | | | | | | | | | |
| 9 | | Time overrun | | | | | | | | x | |
| 10 | | Client satisfaction on time | | | | | | | | | |
| 11 | Cost | Cost | | x | x | x | | | | x | x |
| 12 | | Cost certainty | | | | | | | | | |
| 13 | | Price competition | | | | x | | | | | x |
| 14 | | Tight cost | | | | | x | | | | x |
| 15 | | Within budget completion | | | x | | x | | | | |
| 16 | | Unit cost | | | | | | | | | |
| 17 | | Cost overrun | | | | | | | | | |
| 18 | | Certainty (over time and cost) | | | | | | x | | | |
| 19 | | Value for money | | | | | | | | | |
| 20 | Quality | Quality of the end product | | x | x | x | | x | | x | |
| 21 | | Quality of the process | | x | x | x | | x | | x | |
| 22 | Flexibility | Flexibility | | | | | | | | | |
| 23 | | Possible flexibility and variations | | x | | | | | | | |
| 24 | Risk (allocation/responsibil | Risk avoidance and responsibility | | | | x | | | | | |
| 25 | | Risk allocation | | x | | x | | x | x | | x |
| 26 | | Clients willingness to take risks | | | | | | | | | |
| 27 | | Level of risk to the clients | | | | x | | | | x | x |
| 28 | | Responsibility | | | | | | x | x | | |
| 29 | | Clear division of roles and responsibilities | | | | x | | | | | |
| 30 | | Unknown site risk factors | | | | x | | | | | |
| 31 | | Known site factors likely to cause problems | | | | x | | | | | |
| 32 | | Safety issues | | | | | | | x | | |
| 33 | Complexity | Building complexity | | | | | | | | | |
| 34 | | Complexity, the suitability of the procurement method in handling complex projects | | | | | | | | | |
| 35 | | Complexity | | | x | x | x | | | | |
| 36 | | Size of project | | | | | | x | | | |
| 37 | | Project type | | | | | | | | | |
| 38 | | Building construction type | | | | | | | | | |
| 39 | Innovation | Project requirements | | | | | Is there the possibility for innov | x | x | | |
| 40 | | Need for buildability | | | | | | | | | |
| 41 | | Need for creativity and innovation in the design | | | | x | x | x | | | |
| 42 | | Importance of sustainability in design and material | | x | | | x | x | | | |
| 43 | | Highly serviced or technically advanced building | | | | | | | | | |
| 44 | | Clients requirement for aesthetic building | | | | | | x | | | |
| 45 | | Usage of pioneering technology | | | | | | usage of proven technology | | | |
| 46 | Modern concepts/tools | Importance of utilizing the supply chain concept | | | | | | | | | |
| 47 | | Facilitating lean construction | | | | | | | | | |
| 48 | | Application of value engineering | | | | | | | | | |
| 49 | | Need for the application of BIM | | | | | | | | | |
| 50 | | Need for e-procurement | | | | | | | | | |
| 51 | Cost during the usage phas | Importance of operating and maintenance costs | | | | | optimal management and maintenance | | | |
| 52 | | Low maintenance cost | | | | | | | | | |
| 53 | | Low operational cost | | | | | | | | | |
| 54 | Involvement of the client | Kept informed and actively involved at all stages of the project | | | | | | | | x | |
| 55 | | Clients willingness to be involved | | | | | | | | x | |
| 56 | Relational | Contractual relations and legal relations between parties | | | | | | | | | |
| 57 | | Functional relations between parties | | | x | | | | | | |
| 58 | | Phasing of the building process and the time of participation of parties | | | x | | | | | | |
| 59 | | | | | | | | | | | |
| 60 | | **External environment factors** | | | | | | | | Political decision making | Permits |
| 61 | External environment | Technology feasibility | | | | | | | | | |
| 62 | | Regulatory feasibility | | | | | | | | | |
| 63 | | Materials availability | | | | | | | | | |
| 64 | | Availability of experienced contractor | | | | | | | | | |
| 65 | | Labour productivity | | | | | | | | | |
| 66 | | Industrial actions | | | | | | | | | |
| 67 | | Markets competitiveness | | | | | | | | | |
| 68 | | Political constrains | | | | | | | | | |
| 69 | | Stakeholders | | x | x | x | x | x | | | x |
| 70 | | Bestemmingsplan | | | x | | x | | | | |
| 71 | | | | | | | | | | | |
| 72 | | **Client characteristics** | | | | | | | | | |
| 73 | Client characteristics | Client characteristics in literature | | Communication | Communication | | Capacity and organisation of the client | | | | |
| 74 | | Clients experience | | x | | | | | | x | |
| 75 | | Client type (primary/secondary) | | | | | | | | | |
| 76 | | Clients trust towards other parties | | | x | | | | | | |
| 77 | | Clients financial capability | | | | | | | | | |
| 78 | | Clients in-house technical capabilities | | x | | x | x | | | x | x |
| 79 | | | | | | | | | | | |
| 80 | | | | | | | | | | | |

Table 6 Criteria per interview

## 3.4 Conclusion from the interviews

It can be concluded that the main headings from the literature are in line with the information from the interviews. Especially the clients organisation was mentioned often as an important aspect. The culture and knowledge needs to be present in order to be able to procure in a orderly manner. The external environment was also mentioned a couple of times. However, the meaning in the interviews was different than that from the literature. In the literature the external environment was focused on labour productivity and availability of materials, industrial actions and market competiveness. While in the interviews only political constrains correspond to the criteria mentioned in the literature under the main heading of external environment. Stakeholders, in that sense, were much more mentioned as part of the external environment. All in all, the literature forms a good starting point for the criteria and main headings for the model and the interviews emphasized some main headings more than others, highlighting the relative importance for the Dutch moveable bridge sector.

Overview of the interviews in the appendices
Appendix:
B: Interview 1
C: Interview 2
D: Interview 3
E: Interview 4
F: Interview 5
G: Interview 6
H: Interview 7
I: Interview 8

# 4. Initial model

First the set-up of the model will be explained followed by how the literature and interviews serve as input for this model and how the specific statements and main headings are derived from the literature and interviews.

## 4.1 The set-up of the procurement model

Based on the literature and the interviews the model need to be user friendly and unambiguous to use. The multi-attribute approach seems promising due to its simplicity and user friendliness when compared with an analytical hierarchy process or case based reasoning approach. In the analytical hierarchy process it is possible that the user need to keep adjusting his input in order to get a inconsistency ratio that is low enough for usage of the model. This makes this method tedious and unpleasant to use. The case based reasoning approach is limited in its applicability. Only cases that have matching criteria with the cases in the database are useful. Thereby, this approach proposes only 'old' solutions to new cases. This impedes the innovation in the procurement selection. The multi-attribute approach is user friendly in its use when compared with the analytical hierarchy process and the case based reasoning approach. The client only has to give his input once. Furthermore, this approach is not limited by a database. In theory this approach should be able to propose a procurement strategy for any project.

When it comes to the unambiguity of the criteria, the interviews showed that a main heading can be very important to a client, but the client might not agree with the meaning of that specific criteria. For instance, when looking at the NEDO criterion of flexibility: 'Are variations necessary after construction has started?'. It can be the case that flexibility is important in the design stage and not in the construction phase. Furthermore, in a multi-attribute approach the experts determined the utility factors (weighting factors) for the different criteria for every procurement strategy incorporated in the model and the client assigns his relative importance to the criteria. In a multi-attribute approach this results in a sum per procurement strategy out of which the highest sum is the most applicable procurement strategy. As shown in table 4.

However, since every project is unique in its own way, it is challenging to predetermine the utility factors for every moveable bridge project. Therefore, the idea is to let the client set its own weighting factor for the main headings since the client is the most informed of his own project. Instead of experts predetermining all the utility factors for every project. Thus the client can assign his own weighting factors to the different main headings. Subsequently, for each main heading there should be statements concerning the different criteria, in order that the client can agree or disagree with the statements. The (dis)agreement with the statements will be compared with benchmark scores for the different types of contracts in the model. In case the scoring for a statement and the benchmark score match then the result is a 1 which will be multiplied with the weighting factor. In case the scoring for the statement and the benchmark score don't match then the result is a 0. The type of contract with the highest total sum of all the weighting factors multiplied with 1 or 0 is the advised contract. This is in line with the multi-attribute approach in which the best matching procurement strategy should have the highest total sum. The benchmarks scores for every contract are based on the literature and the interviews. The weighting factor for every main heading is determined by the client.

The items that are fixed in the model are the main headings with the accompanying statements per main heading and the types of contracts with their distinct benchmark scores. Furthermore, the model is set-up in such a manner that future adjustments and additions can be executed in order to keep the model up to date.

Microsoft excel is used for this model. This Microsoft excel model is set up using three tabs, the first tab is where the client assigns his weighting to the main headings. The second tab is for the scoring of the statements for all the main headings. In the third tab are the benchmarks per type of contract. The first two tabs are in line with the main headings and criteria per main heading as can be seen in appendix A. The third tab is where the input of the client is compared with benchmark scores for the types of contracts that are incorporated in the model.

In the first tab of this model each client should assign his own importance weightings for his project. Different weightings per main heading can be given in case a specific main heading is more important for this project than others. In the case that no main heading is more important than another one, then all the main headings should be given the same weighting. The client however can only assign a limited amount of points over the different main headings, this forces the client to compare the importance of each main heading with the other ones. This limited amount of points is set at 55. This number is chosen in order that all the main headings, eleven in total, can be equally important and of average importance to the clients project, a weighting of 5 per main heading. Furthermore, a total of 55 points gives the possibility to really deviate the scores between the main headings. The first tab of the contract advise model is visible in figure 2.



**Figure 2 First tab of the contract advise model**

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In the second tab the client gives a score on whether a specific statement is in agreement or disagreement with his project and viewpoint. This is done via a five point Likert scale. The client can choose one of the following answers for every statement: completely agree, agree, neutral, disagree and completely disagree. This system of weighting and scoring is based on the articles from the literature study which also used a ranking or weighting per factor or criteria[2].

There are two statements per main heading in this second tab. For instance, in the appendix A under the main heading time the criteria 'speed (early completion)' and 'time certainty' are present in most literature. These two criteria are translated in the model as 'certainty that the project is accomplished before a fixed delivery date' and 'a short as possible design + build time is desirable'. These two distinct statements, under the main heading of 'time' can each be scored individually. This way all the statements can be scored in the second tab. The score by the client shows if the statement is in line with the vision of the client and the project. The second tab is showed in figure 3.

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Main heading | Statement | Input field | |
| 2 | Cost | Certainty of the total costs in an early stage is important | | |
| 3 | Cost | Pure price competition is desirable | | |
| 4 | | | | |
| 5 | Time | Certainty of delivering the project before or on a fixed delivery date is important | | |
| 6 | Time | The desire of achieving the shortest time span for the project (design + build time) | | |
| 7 | | | | |
| 8 | Quality | The quality of the end product should be above average, even if this implies extra costs | | |
| 9 | Quality | The quality in the design process is of importance to the client | | |
| 10 | | | | |
| 11 | Flexibility | The possibility for changes in the design phase is desired | | |
| 12 | Flexibility | The possibility for changes in the constructions phase is desired | | |
| 13 | | | | |
| 14 | Risks | A contractor can take on a risk from the client | | |
| 15 | Risks | Transfer of risks from the client to the contractor is desirable | | |
| 16 | | | | |
| 17 | Complexity | The project is highly specialized or technologically advanced | | |
| 18 | Complexity | The project has high performance requirements | | |
| 19 | | | | |
| 20 | Innovation | The space for the contractor to come up with innovative or alternative solutions | | |
| 21 | Innovation | Usage of proven technology is desirable | | |
| 22 | | | | |
| 23 | Costs in the usage phase | Low maintenance cost in the usage phase are important (life cycle costing is part of the clients decision making) | | |
| 24 | Costs in the usage phase | Low operational cost are important in relation to the investment cost | | |
| 25 | | | | |
| 26 | Involvement of the client | It is important to be kept up to date and involved in all the stages of the project | | |
| 27 | Involvement of the client | Does the client trust other parties, in order to be less involved | | |
| 28 | | | | |
| 29 | External environment | Stakeholders have influence on the project | | |
| 30 | External environment | The surrounding environment imposes limitations on the project | | |
| 31 | | | | |
| 32 | Client characteristics | Does the clients has experience with building similar projects | | |
| 33 | Client characteristics | The clients has in-house expertise to design | | |
| 34 | | | Completely agree | |
| 35 | | | Agree | |
| 36 | | | Neutral | |
| 37 | | | Disagree | |
| 38 | | | Completely disagr | |

**Figure 3 Second tab of the contract advise model**

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[2] A ranking per criteria in *Modern selection criteria for procurement methods in construction* (Naoum & Egbu, 2018), a weighting by experts in *Which procurement system* (Skitmore & Marsden, 1988) and weighting per criteria by the client in *Participatory action research approach to public sector procurement* (Love, Edwards, Irani, & Sharif, 2012)*, An analytical hierarchy process based procurement selection method* (Cheung, Lam, Leung, & Wan, 2001) and in *'Contractering bij bouwprojecten'* (De Koning & Sproncken, 2001).

The third tab in the excel model serves as a benchmark score for different contract types, these benchmarks are taken from the literature and interviews or expert judgement. The total input from the client (weighting of main heading and score per statement) for all the statements can be compared with the benchmarking scores in order to calculate the total score for each contract type incorporated in the model. The contract type with the highest sum is the contract that will most likely best suit the clients project.

The comparison with the clients score in the third tab goes as follows. Every type of contract incorporated in the model has three columns in the model. In the first column are the benchmarks scores for the statements. For instance, RAW-bestek for the main heading *cost* and statement *Certainty of the total costs in an early stage is important* has benchmark score *Completely agree* (figure 4: column E, row 3). In the second column for this contract, called 'RAW score' (column F, row 3), is a formula that compares the score of the client for this statement with the benchmark score. In case the client's score and the benchmark are similar, a number 1 is the result of the formula. In case the client's score is different than the benchmark score, a number 0 is the result of this formula. The third column for this example is called 'RAW score*W' (column G, row 3). This multiplies the 1 or 0 with the weighting factor from the client for this main heading, in the case of this example with the weighting factor for the main heading *costs* from tab 1. The sum of this 'RAW score*W' column is calculated. The same goes for the other types of contracts incorporated in the model and the sum is calculated for every type of contract incorporated in the model. The type of contract with the highest sum is the type of contract that is advised for the client's project, since it is best matching the project and client's desires. This can be seen in figure 4.

| | Main heading | Statement | Input field | Weighting factor | RAW-bestek | RAW score | RAW Score*W | Design & Build | DB score | DB Score*W | Design, Build & Maintenance | DBM score | DBM Score*W | Turnkey | TK score | TK Score*W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Cost | Certainty of the total costs in an early stage is important | 0 | 0 | Completely agree | 0 | 0 | Agree | 0 | 0 | Agree | 0 | 0 | Agree/Neutral | 0 | 0 |
| 4 | Cost | Pure price competition is desirable | 0 | 0 | Completely agree/Agree | 0 | 0 | Agree/Neutral | 0 | 0 | Agree/Neutral | 0 | 0 | Neutral/Disagree | 0 | 0 |
| 5 | | | | | | | | | | | | | | | | |
| 6 | Time | Certainty of delivering the project before or on a fixed delivery date is important | 0 | 0 | Agree/Neutral | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 7 | Time | The desire of achieving the shortest time span for the project (design + build time) | 0 | 0 | Disagree/Completely disagree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree | 0 | 0 |
| 8 | | | | | | | | | | | | | | | | |
| 9 | Quality | The quality of the end product should be above average, even if this implies extra costs | 0 | 0 | Agree/neutral | 0 | 0 | Agree/Neutral | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely disagree | 0 | 0 |
| 10 | Quality | The quality in the design process is of importance to the client | 0 | 0 | Neutral/Disagree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 11 | | | | | | | | | | | | | | | | |
| 12 | Flexibility | The possibility for changes in the design phase is desired | 0 | 0 | Completely agree/agree | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely disagree | 0 | 0 |
| 13 | Flexibility | The possibility for changes in the constructions phase is desired | 0 | 0 | Neutral/Disagree | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely disagree | 0 | 0 |
| 14 | | | | | | | | | | | | | | | | |
| 15 | Risks | A contractor can take on a risk from the client | 0 | 0 | Disagree/Completely disagree | 0 | 0 | Agree/Neutral | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree | 0 | 0 |
| 16 | Risks | Transfer of risks from the client to the contractor is desirable | 0 | 0 | Neutral/Disagree | 0 | 0 | Agree | 0 | 0 | Completely agree | 0 | 0 | Completely agree | 0 | 0 |
| 17 | | | | | | | | | | | | | | | | |
| 18 | Complexity | The project is highly specialized or technologically advanced | 0 | 0 | Agree/Neutral | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely disagree | 0 | 0 |
| 19 | Complexity | The project has high performance requirements | 0 | 0 | Agree/Neutral | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely disagree | 0 | 0 |
| 20 | | | | | | | | | | | | | | | | |
| 21 | Innovation | The space for the contractor to come up with innovative or alternative solutions | 0 | 0 | Disagree/Completely disagree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Disagre | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 22 | Innovation | Usage of proven technology is desirable | 0 | 0 | Agree | 0 | 0 | Neutral/Disagree | 0 | 0 | Neutral/Disagree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 23 | | | | | | | | | | | | | | | | |
| 24 | Costs in the usage phase | Low maintenance cost in the usage phase are important (life cycle costing is part of the clients decision making) | 0 | 0 | Neutral | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 25 | Costs in the usage phase | Low operational cost are important in relation to the investment cost | 0 | 0 | Agree/Neutral | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 26 | | | | | | | | | | | | | | | | |
| 27 | Involvement of the client | It is important to be kept up to date and involved in all the stages of the project | 0 | 0 | Completely agree/Agree | 0 | 0 | Neutral/Disagree | 0 | 0 | Neutral/Disagree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 28 | Involvement of the client | Does the client trust other parties, in order to be less involved | 0 | 0 | Disagree/Completely disagree | 0 | 0 | Agree | 0 | 0 | Completely agree | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 29 | | | | | | | | | | | | | | | | |
| 30 | External environment | Stakeholders have influence on the project | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 31 | External environment | The surrounding environment imposes limitations on the project | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 32 | | | | | | | | | | | | | | | | |
| 33 | Client characteristics | Does the clients has experience with building similar projects | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 34 | Client characteristics | The clients has in-house expertise to design | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 35 | | | | | | | | | | | | | | | | |
| 36 | | | | | | Sum | | | | Sum | | | | Sum | | | Sum |
| 37 | | | | | | | 0 | | | | 0 | | | | 0 | | 0 |

Figure 4 Third tab of the contract advise model

## 4.2 Input for the procurement model

The criteria from the literature and the interviews can all be seen in appendix A. This spreadsheet first captures the literature in a chronological order followed by the interviews. The criteria are grouped, for instance all criteria that deal with the topic of time are captured under the main heading 'time'. This is done for all criteria and each main heading has its own background colour for convenience. These main headings serve as starting point for the input for the procurement advise model. Thirteen main headings can be seen in Appendix A, eleven of these main headings are used as main heading in the first tab of the excel model.

### 4.2.1 Excluded main headings

The main heading 'Relational' is not included in the model since it emphasizes the relations in the organisation of the project once a contractor is involved. Therefore, this is not a distinctive factor for a procurement selection method. Besides, is it only mentioned in 'Contractering bij bouwprojecten'. The main heading 'Modern concepts and tools' is not included in the model either, the reason for this is that the use of these concepts and tools is not limited to some contracts. If a client wants to have a BIM model than he can have one with all the contracts that are in this model. The only difference being that he can make this model himself, or hire a party to do it for him, in case of a traditional strategy or write down the demand for a BIM model in the specifications when going for an integrated type of contract. The same goes for the other concepts and tools under this mean heading except for E-procurement. E-procurement is a method of tendering your project. As mentioned in the article where this factor came from, E-procurement can be used for all types of contracts except for partnering (Samuel George & Egbu, 2016). This is due to the fact that for partnering the contractors are chosen strategically and/or on the basis of trust. However, partnering is not included as a contracting type in this model. Thereby, E-procurement deals with finding the right contractor for your project, it is not a distinctive criterion for a certain type of contract used in this study.

### 4.2.2 Main headings

The eleven main headings that are used are:

- Cost
- Time
- Quality
- Flexibility
- Risks
- Complexity
- Innovation
- Cost in the usage phase
- Involvement of the client
- External environment
- Client characteristics

These main headings are all explained to get a clear understanding of their meaning. These definitions are composed out of the definitions given for these topics in the literature and interviews.

- Cost encompasses the total cost to obtain the project.
- Time has to do with the total time of the project, from setting up the contracting strategy until completion of the project.
- Quality has to do with the level of the properties and conditions both in product and process.
- Flexibility has to do with the possibility for variations. Due to uncertainties at this moment the possibility for some flexibility is needed in the project and thus should be taken into account.
- Risks has to do with the uncertainties in the project that can have a negative influence on the final result. It also has to do with responsibility for risks. Who is responsible and for what risk.
- Complexity encompasses the degree of difficulty of the project. This difficulty can be induced by a variety of sources.
- Innovation comprehends everything from designing in an environmental and sustainable way, using pioneering technologies and creativity and knowledge from the market.
- Cost in the usage phase comprehends the cost of operation and maintenance when the moveable bridge is in use.
- Involvement of the client has to do with the manner in which the client wants to be involved in the project. It might be that the client doesn't have staff available for the project and therefore wants to hire a contractor to do everything for him. Or, the client might want to know every detail of the project since it is of major importance to him.
- External environment is based on the information from the interviews, where it encompasses the stability of the scope of the project due to stakeholder involvement in the project. This main heading is based on the interviews because they emphasized the viewpoint for the Dutch moveable bridge sector.
- Client characteristics comprehends the characteristics of the client, is it an experienced client and does he have in-house expertise for instance.

Next is the explanation how the statements per main heading are derived from literature and interviews. Followed by the benchmark scores for the four contract types. The benchmarks scores for each of these contracts for every statement are taken from literature, interviews, the UAV and the UAV-GC. Wherever there was ambiguity concerning a benchmark, the most applicable benchmark for the Dutch moveable bridge sector was chosen. In cases where the literature and interviews did not provide a benchmark, expert judgment was used.

The reference scores in every benchmark are set up in such a manner that they fit the meaning of the type of contract, regardless of the benchmark scores for the other contract types. For instance, the contract types Design & Build and Design, Build & Maintain can have the same score for multiple statements . However, there needs to be at least one type of contract that scores different than all others for each statement. Otherwise, this specific statement is not a distinctive one and could be removed from the model. The model is not based on equal chances for the different contract types for becoming the advised contract. The model is based on reaching the right type of contract for a specific project. Due to the different properties and applicability's of the contracts, the ranges of the contracts vary and so do their chances. This in itself makes it illogic to try to achieve equal chances for the different contract forms.

### 4.2.3 Cost

Almost all the articles from the literature study mention costs when it comes to main headings that are of influence on the procurement. Six out of eleven articles mention the 'certainty of the costs' (Designing buildings, 2016), (Masterman & Gameson, 1994), (Cheung, Lam, Leung, & Wan, 2001), (Luu, Thomas Ng, & Chen, 2005), (Love, Edwards, Irani, & Sharif, 2012), (Samuel George & Egbu, 2016) and seven out of eleven mention the 'competition on price' (Designing buildings, 2016), (Skitmore & Marsden, 1988), (Masterman & Gameson, 1994), (Cheung, Lam, Leung, & Wan, 2001), (Luu, Thomas Ng, & Chen, 2005), (Love, Edwards, Irani, & Sharif, 2012), (Samuel George & Egbu, 2016). During the interviews cost was mentioned too, price competition, tight cost and within budget completion were mentioned multiple times. Since cost certainty and competition on price are mentioned in different interviews and more than 50% of the investigated papers, these two are incorporated in the model as statements. The two statements are *certainty of the total costs in an early stage is important* and *pure price competition is desirable.*

The benchmarks scores for the first statement: *the certainty concerning the total cost of the building project are important at an early stage* is prone to debate. According to 'Contractering bij bouwprojecten' (2001) the total building costs cannot be estimated exactly in a RAW-bestek type of contract (De Koning & Sproncken, 2001). While 'An analytical hierarchy process based procurement selection method' (2001) mentions that this traditional type of contract offers the highest certainty of cost (Cheung, Lam, Leung, & Wan, 2001). After checking this with an expert, it became clear that RAW-bestek should have the highest score on certainty of the total cost. In descending order of certainty at an early stage the integrated forms of Design & Build and Design, Build & Maintain follow second and the Turnkey type of contract takes the third place (Cheung, Lam, Leung, & Wan, 2001). The experts opinion was based on the fact that in a RAW-bestek the client, or a party on his behalf, creates a design for which a good price estimate can be given before the tendering process is started. While in integrated contact forms the client does not have this price estimate. He is depending on the contractor's design and accompanying price, which only become clear after the tender phase.

The benchmarks scores for the second statement *pure price competition is desirable* are as follows. RAW-bestek scores high on this statement, competition on price is possible since design and construction are separated (Centrum voor aansprakelijkheidsrecht, Universiteit van Tilburg, 2005). Based on the design fair price competition is possible. In a Design & Build contract the different designs are less easy to compare, EMVI criteria can be of help to attain the highest price/quality ratio. On the other hand, projects with high requirements with regard to costs and time can best be executed with integrated contracts (Nahapiet & Nahapiet, 2006). Furthermore, there is a transfer of risk from the client to the contractor, this increases the price when compared with a RAW-bestek. The contract type turnkey is not really suited for competition on price since the requirements need to be determined (Cheung, Lam, Leung, & Wan, 2001).

### 4.2.4 Time

The main heading time was at least mentioned once in every article from the literature study. Most mentioned are whether the 'speed (early completion)' (Designing buildings, 2016), (Skitmore & Marsden, 1988), (Cheung, Lam, Leung, & Wan, 2001), (Luu, Thomas Ng, & Chen, 2005), (Nahapiet & Nahapiet, 2006), (Love, Edwards, Irani, & Sharif, 2012), (Samuel George & Egbu, 2016) of the project is desired and 'the certainty of time' (Designing buildings, 2016)*, (Masterman & Gameson, 1994)*, (Luu, Thomas Ng, & Chen, 2005)*, (Love, Edwards, Irani, & Sharif, 2012)*, (Samuel George & Egbu, 2016). Other criteria that are mentioned are: 'time (total time, the design + build time)' (Naoum & Mustapha, 1994)*, 'on-time completion' (Luu, Thomas Ng, & Chen, 2003)*, 'pre-construction time', 'time overrun' and 'the clients satisfaction on time' (Naoum & Mustapha, 1994). The criteria 'speed (early completion)' is mentioned in seven out of the eleven articles and the 'certainty on time' is mentioned in five of the eleven articles. The importance of the criteria 'time' and 'on-time completion' was also mentioned in the interviews. Therefore, the two statements for the model are about the *certainty of delivering the project before or on a fixed delivery date is important* and about *the desire of achieving the shortest time span for the project (design + build time)*.

The benchmarks scores for the first statement *certainty of delivering the project before or on a fixed delivery date* are as follows. RAW-bestek scores somewhat neutral because generally the contractors planning is used. However, a delivery date can always be stated. Therefore, RAW-bestek scores somewhat neutral on this statement (Chao-Duivis, Koning, & Ubink, 2013). Design & Build, Design, Build & Maintain and Turnkey score high on this statement since projects with high requirements with regard to costs and time can best be executed with integrated contracts (Nahapiet & Nahapiet, 2006).

The benchmarks scores for the second statement *the desire of achieving the shortest time span for the project (design + build time)* are as follows. With the RAW-bestek the design and construction take place separately. Building work cannot be started until the design has been completed and the tendering procedure has ended (De Koning & Sproncken, 2001). Thanks to fast tracking in a Design & Build or Design, Build & Maintain, implementation can already be started if the design is still being worked out at detail level (Love, Edwards, Irani, & Sharif, 2012). Fast tracking is also applicable to Turnkey contracts. In addition, the contractor finances the project until the transfer and payment takes place. The contractor benefits from keeping the financing costs as low as possible and thus delivering the project as quickly as possible (De Koning & Sproncken, 2001); (Cheung, Lam, Leung, & Wan, 2001).

### 4.2.5 Quality

Quality is described differently in the different articles. Some articles only capture the quality level of the end product (Cheung, Lam, Leung, & Wan, 2001), or stated more elaborate as 'the importance of high quality of the project, in terms of material, workmanship and design concept' (Designing buildings, 2016) (Love, Edwards, Irani, & Sharif, 2012). While others also take into account the way the project is realized, the quality of the building process. The quality of the building process is described as 'the quality level, including aesthetics, confidence in design, and flexibility in accommodating design input by the client' (Skitmore & Marsden, 1988). Furthermore, it is emphasized that when prestige quality work is specified, clients should consider choosing a procurement system that best utilizes the expertise of the contractors (Thomas Ng, Luu, Chen, & Lam, 2002) (Luu, Thomas Ng, & Chen, 2005) (Skitmore & Marsden, 1988).

It can be clearly seen that the articles that capture quality differ in their horizon and how they look towards quality. This difference in product quality and process quality is mentioned in the literature as well as in the interviews. Most of the interviewees mentioned quality, in product and in process, as important criteria. Interviewee 5 mentions that clients have process requirements concerning how the design is established, which can be seen in Appendix F. Since the process quality and the product quality have their distinct features in a building project, they are both captured in the model with two distinct statements. The first statement concerns the product quality: *the quality of the end product should be above average, even if this implies extra costs*. The second statement concerns the process quality: *the quality in the design process is of importance to the client*.

The benchmarks scores for the first statement *the quality of the end product should be above average, even if this implies extra costs* are as follows. For traditional contract forms such as RAW-bestek, securing in specific descriptions and specifications applies and checking these. Design & Build means securing performance and results instead of direct descriptions and specifications (De Koning & Sproncken, 2001). It is therefore partly dependent on how well the specifications are expressed. In case of Design, Build & Maintain the contractor wants to deliver good quality too, otherwise he will penalize himself with higher maintenance costs. Turnkey, however, is not a suitable contract form if the quality of the end product is an important driver (Skitmore & Marsden, 1988) since the requirements and design are both determined by the contractor.

The benchmarks scores for the second statement *the quality in the design process is of importance to the client* are as follows. The client prepares the design and RAW specifications himself, or has this done for him. The quality in the design process depends on the client and his guidelines for doing this (De Koning & Sproncken, 2001). In Design & Build, Design, Build & Maintain and Turnkey, the contractor must demonstrate according to the quality plan how he does the design process. There are guidelines and standards for this (Chao-Duivis, Koning, & Ubink, 2013).

### 4.2.6 Flexibility

Flexibility is mentioned as an important main heading in six out of the eleven articles. The flexibility and ability in accommodating design changes by the owner is mentioned (Skitmore & Marsden, 1988), (Cheung, Lam, Leung, & Wan, 2001). These variations can be necessary after the work has begun on-site (Designing buildings, 2016), (Love, Edwards, Irani, & Sharif, 2012) or during the design stage (Samuel George & Egbu, 2016). Flexibility is also mentioned in an interview as the possibility to accommodate changes. All in all, the definitions are relative similar in the articles and interview. Flexibility is described as the ability to accommodate changes, these changes can be in the designing stage or when construction works has begun. Therefore, the two statements for flexibility have to do with *the possibility for changes in the design phase is desired* and *the possibility for changes in the constructions phase is desired*.

Flexibility is an interesting main heading concerning the benchmark scores since the investigated articles have contradicting results. In the article 'A comparison of contractual arrangements for building projects' (2006) it is mentioned that "*Design & Build provided a high degree of flexibility and response to changes at all stages of the project*" (Nahapiet & Nahapiet, 2006). While the book 'Contractering bij bouwprojecten' (2001) mentions that adjustments initiated by the client are difficult. It is only possible to effectuate them when clear rules have been set on beforehand. Thereby, integrated contracts require some distance by the client. Adjusting the program of requirements is possible, but is becoming increasingly difficult (De Koning & Sproncken, 2001). In this case the decision was made to adopt the viewpoint from 'Contractering bij bouwprojecten' (2001). This is done because this book was written for the Dutch building industry in particular. Furthermore, this statement is in line with the UAV-GC (Chao-Duivis, Koning, & Ubink, 2013), the Dutch guideline for integrated contracts. In the UAV-GC it is stated that clients should be very cautious in ordering variations. Integrated contracts are not meant for a client to be overly involved with the works. The consequence of this involvement is transfer of responsibility from the contractor to the client, which can have financial implications. The benchmarks for the two statements are as following.

The benchmarks scores for the first statement *possibility for changes in the design phase* are as follows. In the RAW-bestek the client makes the design himself or has it done for him when commissioned. This makes it easy and possible to make changes during the design (Chao-Duivis, Koning, & Ubink, 2013). Design & Build and Design, Build & Maintain are not suited for accommodating interim changes (De Koning & Sproncken, 2001). Only a written request for a change can be submitted. However, this is undesirable since the client then takes on design responsibility. Which goes against the idea of this type of contract (Chao-Duivis, Koning, & Ubink, 2013). Turnkey is not suited for making interim changes in the design phase (Skitmore & Marsden, 1988); (De Koning & Sproncken, 2001).

The benchmarks scores for the second statement *the possibility for changes in the constructions phase* are as follows. When using a RAW-bestek, adjustments in the implementation phase are less easy to implement. If these changes are possible, then they often results in more work and more costs (De Koning & Sproncken, 2001); (Chao-Duivis, Koning, & Ubink, 2013). Design & Build and Design, Build & Maintain are not suited for accommodating interim changes (De Koning & Sproncken, 2001). However, in certain situations a client can submit changes (Chao-Duivis, Koning, & Ubink, 2013). Turnkey is not suited for making interim changes in the construction phase (Skitmore & Marsden, 1988); (De Koning & Sproncken, 2001).

### 4.2.7 Risks

Risks is mentioned in multiple articles often together with responsibilities. The viewpoint concerning risk is different in the different articles. Some articles mention the extent to which 'the client wishes one single organisation to be responsible for the project, or to transfer the risk of cost and time slippage' (Designing buildings, 2016), (Skitmore & Marsden, 1988), (Cheung, Lam, Leung, & Wan, 2001). While other articles mention the 'allocation of risks' (Luu, Thomas Ng, & Chen, 2005) as procurement selection criteria and 'the clients willingness to take risks' (Luu, Thomas Ng, & Chen, 2003). These articles all mention the allocation or transfer of risks.

Risks and the allocation of risks is mentioned often in the interviews. In interview 4 it was mentioned that in case of transferring a risk to a contractor, the contractor must be able to manage or bare the risk. If this is not the case then this can lead to risk premiums that are not mitigating the risk. This is in line with the viewpoint in 'Contractering bij bouwprojecten'. In which it is mentioned that the responsibility for risks should be divided based on who can best manage the risk or manage it for the lowest cost (De Koning & Sproncken, 2001).

The statements for risk, based on the articles and interviews are: *A contractor can take on a risk from the client* and *transfer of risks from the client to the contractor is desirable.* This last statement captures the willingness of the client to take risks or the desire to transfer risks.

The benchmarks scores for the first statement *a contractor can take on a risk from the client* are as follows. In a RAW-bestek the client has the responsibility for the preliminary design and the final design. In a Design & Build the contractor is responsible for the final design (Centrum voor aansprakelijkheidsrecht, Universiteit van Tilburg, 2005). The responsibility for the preliminary design may, depending on the situation, fall under the responsibility of either party. In addition, maintenance is also the responsibility of the contractor in a Design, Build & Maintain. In a Turnkey contract the contractor is responsible for the entire development and the associated financial risk (De Koning & Sproncken, 2001); (Cheung, Lam, Leung, & Wan, 2001); (Skitmore & Marsden, 1988).

The benchmarks scores for the second statement *transfer of risks from the client to the contractor is desirable* are as follows. There is a clear division of responsibilities in a RAW-bestek (Chao-Duivis, Koning, & Ubink, 2013). The contractor is responsible for execution risks, costs and planning. Design & Build is an integrated contract form which means that the contractor will be more responsible when compared with a RAW-bestek (Centrum voor aansprakelijkheidsrecht, Universiteit van Tilburg, 2005). Design, Build & Maintain allocates more responsibility at the contractor than Design & Build since maintenance is also the contractor's responsibility. In a Turnkey contract the contractor is fully responsible for ensuring that the design and implementation meet the requirements (De Koning & Sproncken, 2001); (Cheung, Lam, Leung, & Wan, 2001); (Skitmore & Marsden, 1988).

### 4.2.8 Complexity

Complexity is described as 'the need for a highly specialized, technologically advanced or highly serviced building' (Designing buildings, 2016); (Love, Edwards, Irani, & Sharif, 2012); (Luu, Thomas Ng, & Chen, 2005); (Samuel George & Egbu, 2016). Furthermore, complexity is described in terms of project characteristics such as the 'project type, the project size and the construction type' (Luu, Thomas Ng, & Chen, 2003); (Luu, Thomas Ng, & Chen, 2005); (Samuel George & Egbu, 2016). Complexity is also described as 'the suitability of the procurement method in handling complex projects' (Cheung, Lam, Leung, & Wan, 2001). It is mentioned that heavier client involvement would have a positive effect on the project outcome, especially for complex projects (NWPC, 1990). Complexity is mentioned in a couple of the interviews too as a criteria to keep in mind when setting up the procurement strategy. Furthermore, complexity is only a distinctive factor for Turnkey contracts (NWPC, 1990). The other contracts used in the model (RAW-bestek, Design & Build and Design, Build and Maintain) score practically the same on this main heading (Love, Edwards, Irani, & Sharif, 2012); (Cheung, Lam, Leung, & Wan, 2001).

Additionally, the correlation between complexity and flexibility is mentioned. Complexity and flexibility have a very high positive correlation. Meaning that as complexity increases the need for flexibility also increases (Hertogh & Westerveld, 2010); (Skitmore & Marsden, 1988); (Nahapiet & Nahapiet, 2006). The link between complexity and performance requirements is also emphasized. High complex and high performance requiring projects were managed by contractual arrangements in order to ease co-ordination. The project characteristics, such as complexity, are among the three most important attributes together with the client characteristics and the project requirements (Nahapiet & Nahapiet, 2006).

The main topics that were mentioned in the articles are whether the project is very specialized or technologically advanced and the performance requirements as imposed on the project. The statements for the main heading complexity therefore become: *The project is highly specialized or technologically advanced* and *the project has high performance requirements.*

There is ambiguity concerning the benchmark scores for the criteria complexity. When it comes to complexity the contract form Turnkey scores lowest of the four contract forms according to Marsden (Skitmore & Marsden, 1988). While only Turnkey scores high when compared with the other contracts according to (Cheung, Lam, Leung, & Wan, 2001). The precise definition in the two articles concerning complexity is as follows, Skitmore & Marsden (1988) look at the building complexity while Cheung, Lam, Leung, & Wan (2001) define complexity as the suitability of the procurement method in handling complex projects. Based on these two articles it is unclear which statement should be adopted.

However, as mentioned, flexibility and complexity have a strong positive correlation. Meaning that as complexity increases in the project the flexibility should increase too (Hertogh & Westerveld, 2010); (Skitmore & Marsden, 1988); (Nahapiet & Nahapiet, 2006). By adopting the statement from Cheung, Lam, Leung, & Wan (2001) this positive correlation becomes a negative correlation in the model. The viewpoint from Skitmore & Marsden (1988), Nahapiet & Nahapiet (2006) and Hertogh & Westerveld (2010) is used in the initial model. The reason for this is based on the fact that the three articles mention the same positive correlation while only Cheung, Lam, Leung, & Wan (2001) contradict to this. In order to test if the initial model is functioning correct on this main heading a test will be

performed by using an adjusted initial model for the main heading complexity in which the viewpoint from Cheung, Lam, Leung & Wan (2001) is used. The benchmark score for complexity will be adjusted in this adjusted model because the benchmark score for flexibility is in line with the Dutch guideline. This must show which viewpoint for complexity can be adopted best for the model. The verification session with the case projects will be done based in the initial model. Afterwards, the benchmark scores for the main heading complexity will be adjusted to be in line with the viewpoint from Cheung, Lam, Leung & Wan. The initial model and the complexity adjusted model will be compared for the cases in order to conclude which statement to prefer. This initial model and the complexity adjusted model will be included in the appendix of every case project.

### 4.2.9 Innovation

Innovation as a criteria for the procurement is mentioned in three out of the eleven articles. The definition in these articles are as follows. 'The need for buildability, need for creativity and innovation in the design and importance of sustainability in design and material' (Samuel George & Egbu, 2016). 'The usage of pioneering technology, a highly services or technically advanced building and clients requirement for aesthetic building are mentioned as topics to take in consideration for the procurement' (Luu, Thomas Ng, & Chen, 2003). Lastly, 'project requirements' is mentioned as the overarching term for which innovative solutions must be found (Nahapiet & Nahapiet, 2006). These requirements can be of different origin such as tight costs or speed demands for the project.

For innovation, the criteria 'need for buildability, importance of sustainability in design and material' and 'clients requirement for aesthetic building' are all specific requirements that can be written down in a traditional type of contract or can be written down as a specification for an integrated contract. The 'need for creativity and innovation in the design' and 'the usage of pioneering technology' are not things you write down in the contract or the specifications. These are (innovative) solutions to design or technical problems or other project requirements. Therefore this is described as *the space for the contractor to come up with innovative or alternative solutions* and *the desirability to use proven technology.*

In the interviews innovation was also mentioned, this was most apparent in the interviews 3 and 4, appendices E and F. Interviewee 4 emphasized that 'there might be space in the project for contractors to come up with alternative or innovative solutions'. Interviewee 3, on the other hand, explained how to deal with pioneering technology in a project, that a client prefers proven technology. This results in the following statements for innovation: *There is space for the market to come up with innovative or alternative solutions* and *usage of proven technology is desirable.*

The benchmarks scores for the first statement *there is space for the market to come up with innovative or alternative solutions* are as follows. In the RAW-bestek it must be made according to specifications. At most contractors can propose an alternative (interview 4); (Chao-Duivis, Koning, & Ubink, 2013). In a Design & Build, Design, Build & Maintain and Turnkey contract the contractor is the one who is designing (interview 5); (Chao-Duivis, Koning, & Ubink, 2013) and can therefore induce innovation.

The benchmarks scores for the second statement *usage of proven technology is desirable* are as follows. Interviewee 5 indicated that as a client you prefer proven technology. In a RAW-bestek, the client is designing, or the design is being made on his commands, pioneering technology will be applied less quickly in this type of contract. In a Design & Build and Design, Build & Maintain contract you, as a client, prefer proven technology. If the designer nevertheless proposes pioneering technology, you, as a client, would like to be covered by having FAT and / or SAT done. With an integrated form you want to use the knowledge and skills of the contractor, this also includes pioneering technology (interview 5). Turnkey gives the contractor a lot of design space in this respect and therefore room for pioneering technology.

### 4.2.10 Cost in the usage phase

It is a client's long term objective to have low cost in the usage phase of the project, which primarily concern the life-cycle cost of a project (Luu, Thomas Ng, & Chen, 2003). A method to achieve this in integrated contracts is by making the contractor liable for the maintenance (and operations) for a certain period of time. Then the contractor has a financial incentive to design and build the project in such a way that the costs of maintenance (and operations) are low.

The cost in the usage phase is very important. In a study with 57 construction professionals the importance of maintenance cost was given a shared second place, together with dealing with safety issues. The first place was for flexibility and variations (Samuel George & Egbu, 2016). An interview added that the optimal management of the maintenance is of importance too.

The cost in the usage phase is split up in two components, the maintenance cost and the operational cost. However, there is a trade-off between low cost in the usage phase and the upfront investment cost. It is important to get the balance clear between the investment cost and the maintenance cost for a specific project. Therefore the two statements are: *low maintenance cost in the usage phase are important (life cycle costing is part of the clients decision making)* and *low operational cost are important in relation to the investment costs*.

The benchmarks scores for the first statement *low maintenance cost in the usage phase* are as follows. There is an incentive to design well when the designing party is also responsible for the maintenance costs. In a RAW-bestek, the client will do his best to design as good as possible. The result depends on the expertise of the client or the party hired for designing (Luu, Thomas Ng, & Chen, 2003). In a Design & Build contract the designing party is not responsible for the maintenance cost. Design, Build and Maintain fosters life cycle costs. In other words, an improvement in the costs for maintenance and operations (Luu, Thomas Ng, & Chen, 2003). In a Turnkey contract the commercial risks of the end product are for the buyer, in this case the client (De Koning & Sproncken, 2001).

The benchmarks scores for the second statement *low operational cost are important in relation to the investment costs* are as follows. There is an incentive to design well when the designing party is also responsible for the operational costs. In a RAW-bestek, the client will do his best to design as good as possible. The result depends on the expertise of the client or the party hired for designing. This way, the client can make a trade-off between the operational costs and the investment costs (Luu, Thomas Ng, & Chen, 2003). In a Design & Build contract the designing party is not responsible for the operational cost. This means that there is no incentive for the contractor to weigh the operational costs against the initial investments. Design, Build and Maintain fosters life cycle costs. In other words, an improvement in the costs for maintenance and operations (Luu, Thomas Ng, & Chen, 2003). In a Turnkey contract the commercial risks of the end product are for the buyer, in this case the client (De Koning & Sproncken, 2001). This means that there is no incentive for the contractor to weigh the operational costs against the initial investments.

### 4.2.11 Involvement of the client

Involvement of the client deals with if and how the client wants to be involved in the building process. It is mentioned that a need to be kept informed and be actively involved at all stages of the project is one of the top five concerns, together with the certainty of the final cost and the certainty of the day for completion, when choosing a procurement system (Masterman & Gameson, 1994).

The involvement of the client can be reduced by transferring time and cost risks to the project team. Three variables that are concerned with the involvement of the client are: client's willingness to be involved, client's trust towards other parties and client's willingness to take risks. Based on the client's consideration for each of these three variables the involvement of the client can be increased or reduced (Luu, Thomas Ng, & Chen, 2003). Since the transfer of risks from client to contractor is already mentioned as a factor in the main heading of 'risk', the two main questions that remain are the willingness of the client to be involved and the trust towards other parties. Therefore the statements are: *It is important to be kept up to date and involved in all the stages of the project* and *does the client trust other parties, in order to be less involved?*

The benchmarks scores for the first statement *it is important to be kept up to date and involved in all the stages of the project costs* are as follows. The involvement of the client can be less when time and cost risks are transferred to the contractor. In a RAW-bestek, the client is intensively involved in the design stage and has a controlling role during the construction (Luu, Thomas Ng, & Chen, 2003). In a Design & Build and Design, Build & Maintain the client checks whether the design and execution meet the specifications. The involvement of the client is minimal in a Turnkey contract. The program of requirements or the performance specification is drawn up by the client, it is only at the transfer that there is an inspection as to whether it satisfies before acceptance and payment takes place (De Koning & Sproncken, 2001).

The benchmarks scores for the second statement *does the client trust other parties, in order to be less involved* are as follows. In a RAW-bestek the client prescribes everything and carries out checks to verify whether everything goes as prescribed in the contract (Chao-Duivis, Koning, & Ubink, 2013). In a Design & Build and Design, Build & Maintain the client must trust the contractor and therefore writes specifications which design and construction must meet (Chao-Duivis, Koning, & Ubink, 2013). In a Turnkey contract the client has a lot of confidence in the contractor and outsources everything completely (De Koning & Sproncken, 2001).

### 4.2.12 External environment

According to the literature the main heading external environment encompass multiple criteria, these criteria are: 'technology feasibility, regulatory feasibility, materials availability, availability of experienced contractor, labour productivity, industrial actions, markets competitiveness and political constrains' (Luu, Thomas Ng, & Chen, 2003). These are all topics that one way or another can influence the project without the client being able to influence these topics. For instance, a client will most likely not be able to change the markets competitiveness or have influence on industrial actions. Therefore, these external forces or circumstances can have an influence on the project. The general view at the external environment in the articles is the societal impact and the impact that the construction sector can have on the project.

The topic of the (external) environment is also mentioned in the interviews. However, the interpretation is different from that in the literature. In the interviews the external environment is seen as the physical surroundings of the building project and the people and stakeholders who have an interest in the project. People living nearby a project can object to it, as happened with the Sint Sebastiaansbrug in Delft (Cerberus, 2018). There can be rules concerning monumental buildings and trees but also topics concerning the destination plan. These are all external elements that should be taken into account for the procurement decision. The viewpoint from the interviews is used for the model. The reason for this is because the external environment from the literature is more describing the construction sector and not purely the project context. While the interviews are primarily focused at the project specific context. Furthermore, the interviews highlight the viewpoint of the Dutch moveable bridge sector. Different contracts can be better suited for different projects with their specific context. The statements concerning the external environment encompass the *stakeholders have influence on the project* and *the surrounding environment imposes limitations on the project.*

The benchmark scores concerning the main heading 'external environment' are interesting. The interviews 3 and 4 were contradictory. Interviewee 4 stated that in case the surroundings impose limitations to the project it is best to develop the project in-house. While interviewee 3 mentioned that leaving such situations to the contractor might result in the contractor being able to take away some of the limitations. Interviewee 3 thereby mentions that this also implies an increased risk for contractors, especially when contractors tender with a design that might eventually not be possible in case these limitations cannot be diminished. For this study the viewpoint from interviewee 4 is incorporated in the model. The reason for this is based on the certainty that a project will be realized in a proper manner. The viewpoint from interviewee 3 is reasonable, but this brings in a large amount of extra risk to the project. In case the contractor is not able to build according to the design and plan on which he won the tender, than this implies extra risks and problems to the project. These can have large consequences for the project, such as: (large) delay of the project, the contractor might try to cut corners in order not to lose money on this project or the contractor might even go bankrupt resulting in no construction at all. Other problems that might arise concern the stakeholders in the project who might oppose to the ideas opted by the contractor. This may lead to opposition or even lawsuits against the project. In order to avoid these extra risks from creeping into the project the viewpoint of interviewee 4 is used in this study. Therefore, the benchmark scores for the two statements are as following.

The benchmarks scores for the first statement *there is influence by stakeholders on the project* are as follows. For a RAW-bestek, the more there is influence by stakeholders, the larger the chance of design changes. In that case it is wise to have the design worked out by the client. Because, it is more difficult for a contractor to meet the client's requirements and to deal with a changing scope or design due to stakeholder influence than it is for a client (interview 4); (interview 5). If the influence of stakeholders is low, the contractor can design well on the basis of a program of requirements.

The benchmarks scores for the second statement *the limitations that the surrounding environment puts on the project* are as follows. If the physical surrounding environment imposes limitations, it may be more convenient to make the design in-house, a RAW-bestek is suited for this, integrated contracts are less suited for doing so (interview 4).

### 4.2.13 Client characteristics

It is assumed that the procurement method selected for a project effects the project performance but is not solely determining it. The effect the characteristics of the client, designer and contractor have on the project performance is therefore investigated (Naoum & Mustapha, 1994). Clients can be distinguished on the basis of three variables, these are the in-house capabilities of the client, the experience of the client and the type of client. The 'experience and expertise' are the moderating factors on the performance of procurement chosen (Luu, Thomas Ng, & Chen, 2003). Based on the 'experience and the type of client' (Nahapiet & Nahapiet, 2006) the clients can be further categorized. Clients can be *primary or secondary* clients and they can be *experienced or inexperienced*. Primary clients are clients whose main business and primary income derive from realizing buildings. Secondary clients are those who need a building in order to undertake their business. Inexperienced clients are those who do not have any recent and relevant experience with building similar projects and who do not have established access to construction expertise. Experienced clients are those who do have relevant experience in realizing similar types of projects, with established access to construction expertise, this can be in-house or externally. This results in four types of clients: secondary inexperienced, secondary experienced, primary experienced and primary inexperienced. This last one, however, does not exist since it is very unlikely to be inexperienced in your core business (Masterman & Gameson, 1994).

It turned out that experienced clients were more satisfied when it comes to time and cost performance. This is due to their *in-house expertise* (Naoum & Mustapha, 1994). While contracts such as management contracting and construction management are especially valuable for the clients with little experience and/or limited in-house expertise (Nahapiet & Nahapiet, 2006).

The three factors that are mentioned are: *the business of the client (is it a primary or a secondary client), the level of experience of the clients* and *the in-house capacity/expertise of the client*. In-house capacity and expertise were also mentioned in the interviews. After further investigating the articles it became clear that the two distinct factors are *the level of experience of the clients with building similar projects* and *in-house capacity/expertise of the client.* The question concerning *primary or secondary clients* is actually a question concerning the expertise of the client. A primary client is an experienced client and has in-house expertise or established contacts with expertise companies in order to support him, according to the literature. For secondary clients the determining factors are their level experience and their in-house expertise. The deal whether or not the client is a secondary or primary client is in fact captured in the two distinct factors concerning their level of experience

and the level of expertise. The two statements therefore become: *Does the clients has experience with building similar projects* and *the clients has in-house expertise to design.*

The benchmarks scores for the first statement *does the clients has experience with building similar projects* are as follows. If the client has experience, than he knows exactly what he wants and whether this is possible. This can then be written down in a RAW-bestek (interview 4); (Masterman & Gameson, 1994). Clients who have no experience with similar projects benefit from the knowledge and skills of contractors (Masterman & Gameson, 1994). An integrated contract form would be of use these clients.

The benchmarks scores for the second statement *the clients has in-house expertise to design* are as follows. Clients benefit from the knowledge of the market if they do not have this expertise themselves (Masterman & Gameson, 1994). When a client does have knowledge or expertise, than he often knows what he wants, making a design himself is an option in that case. Clients benefit from the knowledge of the contractors if they do not have expertise themselves (Masterman & Gameson, 1994). An integrated contract form would beneficial to these clients.


The completeness of the model and the scores for the benchmarks for the different contract types are checked by an expert. This expert had two remarks, one concerning the ability of clients to work with the different types of contracts. This is regarded as a prerequisite in this study for working with this model. Therefore, the client organisation should be able to work with different types of contracts, the organisation should be structured accordingly and internal procedures allow this. The other remark concerned the benchmark scores for costs, this remark has been implemented and is explained in paragraph 4.2.3 cost certainty.

The next chapter will highlight the verification, whether or not the model is advising the best type of contract for a project.

# 5. Verification

Verification of the initial model is done with the use of case projects. These case projects all concern moveable bridges that were executed recently in the Netherlands. First the method of verification will be explained followed by the specific cases and their results.

## 5.1 Verification method

The method for verification consist of running the initial model with moveable bridge projects recently realized. The decision for finished bridges is to track down if the chosen type of contract fulfilled its intended role or if another type of contract would have been better with hindsight knowledge. The method for doing this is by interviewing clients and/or project managers who were involved in the contract decision. The verification method encompasses three phases.

### 5.1.1 First phase

In the first phase the interviewee should go back to the situation before the type of contract was chosen for the project. The initial model will be filled in based on this situation. The advice from the model will not (yet) be shown to the interviewee in order to not influence the interview.

### 5.1.2 Second phase

The second phase consist of answering questions with the knowledge of the realized project. These questions are:

- Which contract is used for the project?
- Why is this type of contract chosen?
- What went good in the project? And why it went good?
- What could have been better in the project? And why could it have been better?
- Is there anything that should have been avoided in the project? And why?
- With the current knowledge, would you choose the same contract for this project or another one?
- Why would you choose this contract?/Why would you choose the same type of contract?
- Is there anything else that needs to be mentioned concerning the contract choice?

The answers to these questions must show whether the contract that was used fulfilled the projects and the client's needs. It is illogic to assume that the type of contract is the only determining factor for letting the project go according plan. There are numerous other factors that can influence the progress of the project. The questions in the second phase of the verification are aimed at disclosing what possible factor(s) were of influence for the specific projects and more importantly, how they were dealt with.

### 5.1.3 Third phase

The third phase of the project consists of comparing the advice from the model (result of phase one) with the results from the second phase. Does the advice from the model correspond to the type of contract that was used or the type of contract that would have been chosen with hindsight knowledge. Or does the advice from the model correspond with neither of these two types of contract situations. Most important is to find out why or why not it corresponds to the used contract or contract that was chosen with hindsight knowledge. This can lead to four possible situations, shown in figure 5 verification matrix. Each of the quadrants and their meaning for the verification are further emphasized.
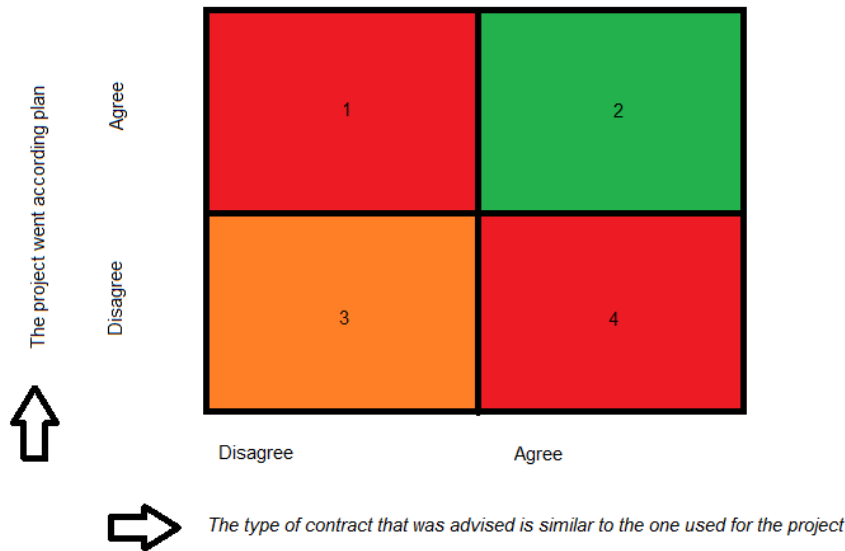
**Figure 5 Verification matrix**

In the top right (quadrant 2) is the ideal situation, the advised type of contract from the model is the same type of contract used for the project and the project went according to plan. This is an indication that the model is functioning. At the bottom left (quadrant 3) is the situation where the advised contract and used type of contract do not match and where the project did not went according plan. This is an indirect clue that the model might be right. It can be the case that the model indeed predicted the best type of contract for that project. It can also be the case that a third type of contract, not used nor advised, would be best for the project. Therefore this situation does not directly show the correctness of the model. Quadrant 1 shows the situation where the advised contract and used contract do not match, but where the project went according plan. This is an indication that the model is not predicting well. Quadrant 4 is the opposite situation of quadrant 1. Here the type of contract matches the advised type of contract but the project did not go according to plan. This too is an interesting situation to find out why things went as they went and how they can be overcome and what role the contract had in this.

It is important to first find out to which quadrant a project belongs and then to find out why it belongs to this quadrant with the questions from the second phase. Furthermore, if the interviewee indicates that another type of contract would be chosen with hindsight knowledge, it is important to know why he would choose this other type of contract. Besides, this other type of contract leads to a hypothetical change of quadrant in which the project is located. Does it move from a red or orange quadrant to the green quadrant? Or does it move away from the green quadrant? Or, as a third option, does it move from a red or orange quadrant to another red or orange quadrant.

In order to find out the interviewee's opinion concerning the advice from the model and its applicability the following three questions are asked:

- According to the model the .... type of contract is advised. What is your opinion concerning this advice?
- Was this type of contract also concerned at that time?
- Would you consider this type of contract with the current knowledge?

### 5.1.4 Remarks

It is important to keep in mind that the type of contract is not the sole determining factor for the course of the project. The client and contractor for instance have influence on the project. It might be the case that they acted in such a way that a non-ideal type of contract can still lead to a satisfying project. The other way around is also possible. All the questions are aimed at clarifying why a project happened as it did.

Furthermore, it is important to consider that interviews always contain a human factor. People might not want to share everything or may be unable to share everything due to confidentiality. As happened during an interview to enrich the literature (chapter 3). All the interviewees were asked if it was okay to record the interview. The purpose of this recording was to not forget certain important parts of the interview when typing them out. This purpose was stated clearly beforehand and it was emphasized that this recording would be treated confidential and would be deleted after this master thesis is finalised. Still, as soon as the recording started one interviewee seemed rather cautious about what he said and how he said things. The interview did not go very smooth and possible confidential information being recorded could have prohibited the interviewee from sharing his viewpoint. Therefore the recording was stopped soon afterwards in order to still gain some knowledge from this interview. Despite the recording being stopped the interview did not proceed as before the recording started. The verification interviews were not recorded to prevent this from happening.

However, cognitive dissonance could also play a role during the interviewees. Cognitive dissonance means that someone (unconsciously) adjusts his or her opinion on a certain aspect in order align it with his or her other opinions (Cherry, 2018). An example of cognitive dissonance in the interviews can be as follows: The interviewee initially wanted to use the best type of contract for the project. Suppose a Design & Build type of contract was deemed suitable and used. After the project was finished it became clear that a RAW-bestek type of contract would have better suited the project. Then the interviewee might be reluctant to admit that RAW-bestek would have been better if it is conflict with his other values such as keeping informed and acquainted with new developments. The interviewee can state a lot of arguments why Design & Build was a good decision, despite the struggles during the project. 'It was an instructive process to get acquainted with the new and popular Design & Build type of contract', for instance.

If during the interview the model shows that a RAW-bestek type of contract is the advised type of contract for the project, then the interviewee might be reluctant to agree with this advice. The interviews are meant to gain knowledge concerning the advice of the model and the functionality of it, but it is important to take this behavioural aspect into account. The verification is set-up in such a way that cognitive dissonance is unlikely to occur due to setup of the interview with the three phases. The advice of the model is shown after the questions in the second phase have been answered. This way the interviewee cannot adjust his answers to the questions in the second phased based on the advice of the model.

## 5.2 Case projects

The cases that were selected for the verification of the initial model are all moveable bridges that were realised in the Netherlands. The verification and the results will be handled per case. The contract advice model as it is filled in by the interviewees during the interviews can be found in the appendices.

### 5.2.1 Case A

For case A an interview was arranged with the consultant that managed the project for the client organisation. He managed the project for a governmental body from the start of the renovation project until completion. In order to make sure that I would get the right person for the verification I contacted the governmental body. After being forwarded a lot the interviewee turned out to be a key person in the process of this renovation project.

#### *The project*

The moveable bridge is part of one of the mayor roads through a city. Besides the daily congestion at this road there is typically seasonal congestion too. The bridge needed maintenance because of its age and intensive use. Thereby, the bridge was prone to malfunctioning.

The clients organisation is set to 'werken op regie', meaning working on directing. Because of this 'werken op regie' a consultancy firm was attracted to set up a contracting strategy for this renovation project. For this renovation the contract type Engineering & Construct was used. This is comparable with Design & Build except that the preliminary (architectural) design is already established. Therefore, the Engineering & Construct contract is located in between the contract types RAW-bestek and Design & Build when looking at the degree of integration. The decision for this type of contract was based on the fact to first reach an agreement with the environment before a contractor was involved. Still the welfare committee was involved a little too late in the process leading to adjustments of the architectural design and thereby leading to technical design adjustments. Despite the fact that the client's side took up the UAV-GC role well, the project eventually went over budget quite a bit. Therefore, more emphasis should have been placed on not going over budget. In order to achieve this, the interviewed consultant would use the contract form Bouwteam if he had to redo the project. The reason for this is because the project perspectives such as planning and cost estimates increase in reliability due to the input of the contractor. All in all, the project is regarded as a success.

#### *Contract advise*

The contract advise from the model is Design, Build & Maintain. The model as it was filled in by the interviewed consultant can be seen in Appendix J. The advice from the model cannot corresponds with the contract that was used for this project since the contract type Engineer & Construct is not included in the model. The interviewee emphasized that Design, Build & Maintain could be considered since it is comparable with the contract type that was actually used. However, this contract type was not considered at that time because maintenance was taken care of in maintenance contracts.

An explanation for the advice for the Design, Build & Maintain contract can be found in the scoring in the contract advice model. A lot of importance was assigned to the main headings: external environment, costs in the usage phase and risks. The contract form RAW-bestek is the second best advice in the model and scores maximum for the main heading external environment. As the

interviewee stated, this external environment was of importance in order to align the different stakeholders. Important stakeholders were the waterway manager, who have had enough of all the malfunctioning of the bridge, and the bus company that drove over the bridge. This bus company received a financial compensation for the delay that was incurred due to the renovation of the bridge. This aligning of the stakeholders was managed in the Engineering & Construct contract by establishing a preliminary design which was approved by the stakeholders. The welfare commission should have been involved more in this stage, according to the interviewee. Furthermore, the advised type of contract from the model, Design, Build & Maintain, scores maximally for the other two important main headings, *costs in the usage phase* and *risks*. This cost in the usage phase was not so much about the cost, it was much more about the reliability in the usage phase. This was particularly important for the waterway manager who wanted a bridge free of malfunctions. Whereas the transfer of risks towards the contractor was desired by the client. Both things for which a Design, Build & Maintain contract is suited.

The project is regarded as successful, even with the cost overrun that had occurred. Despite the fact that advice from the model is not matching the used type of contract, this is still regarded as a valuable verification. The model shows exactly for which important main headings the various contract forms score. Exactly the main headings for which a Engineer & Construct would score well. If the contract type Engineering & Construct was incorporated in the model it would most likely have been advised by the model. Therefore, extending the model with this type of contract is something to consider. Based on this, the project is located in quadrant 2 of the verification matrix.
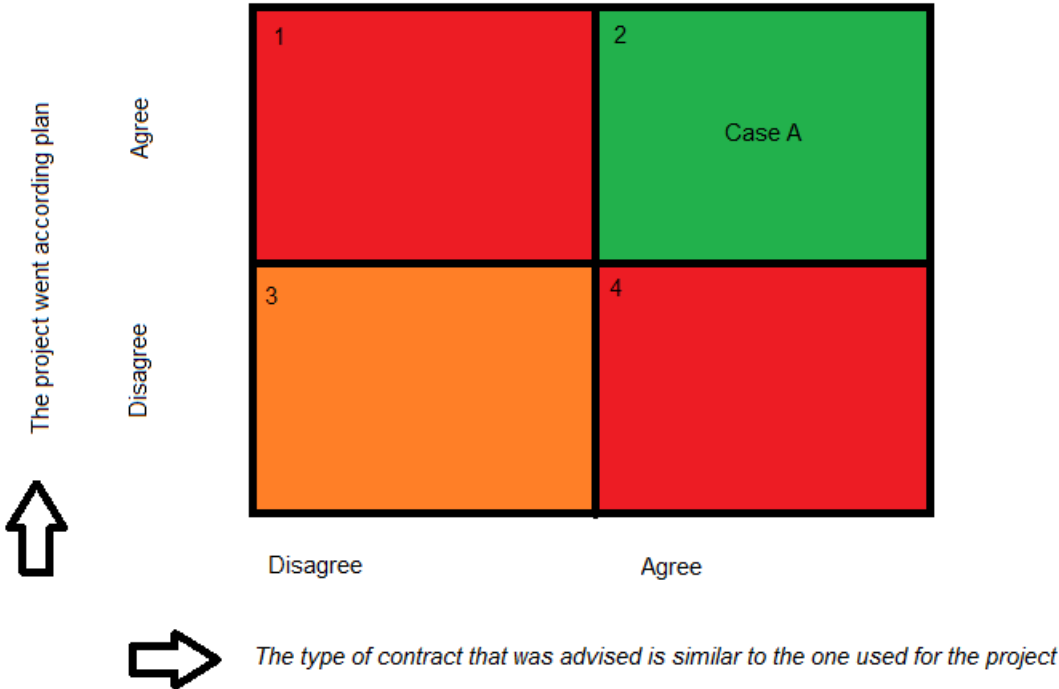


**Figure 6 Verification matrix case A**

### 5.2.2 Case B

An interview was arranged with interviewee B for this project. Interviewee B is part of the client organisation. He was involved in the process for choosing a contract type and kept involved until the completion of the project. The decision for a contract type was made in consultation with specialist of different disciplines of the project. The decision to interview interviewee B is based on the fact that he was involved in the decision of the type of contract and kept involved throughout the project.

#### The project

The moveable bridge was part of a more comprehensive project which involved the construction of several roads. For this project the UAV-GC met concurrentie gerichte dialoog (Design & Build) was chosen as contract type. UAV-GC was the standard contract type for doing these sorts of projects at the clients organisation. The client saw opportunities for innovation induced by contractor(s) and the goal was to benefit from the contractors knowledge. It turned out that there were too much limitations for allowing innovation by the contractor. A striking example, one contractor came up with the plan of constructing a tunnel to cross another road. This reduced hindrance when compared to building a viaduct over this road, since this road does not have to be closed when this tunnel would be constructed. The client, however, had already agreed with the owner of the road on crossing the road by building a viaduct. This limitation was not communicated properly and was in fact a reduction of the design freedom and thereby innovation potential of the contractor.

On the other hand, the bridge serves as an example for the client when it comes to machine safety. The contractor took its responsibility very serious and performed excellent during the FAT and SAT. A thorough book was handed over concerning all the safety procedures being checked.

According to interviewee B they would choose the same type of contract if they had to do this project again, but without the 'concurrentie gerichte dialoog'. Making use of the design capacity of the contractor and allocating corresponding risks at the contractor are reason for choosing this same contract.

#### Contract advise

The contract advise from the model is RAW-bestek. The model as it was filled in by interviewee B can be seen in Appendix K. This advice does not correspond with the contract that was used, Design & Build. According to interviewee B the RAW-bestek form does not match the vision of the client. This contract type was not considered at that time and would also not be considered today. Despite the discrepancy between the advice and the actual contract that was used, the project went according plan. This places the project in quadrant 1 of the verification matrix. An explanation for this can be found in the scoring in the contract advice model.

The main headings *flexibility* and *external environment* only have a match with the benchmark for RAW-bestek. *Flexibility* had a match with the following statement: *The possibility to make adjustments in the design phase is desired.* While *external environment* matched on both the statements: *Influence by stakeholders on the project* and *The limitations that the surrounding environment puts on the project.*

The scoring by the client for these two main headings corresponds with what was mentioned to be somewhat problematic in the project. The RAW-bestek is probably the advice from the model because, with hindsight knowledge, the client wanted to prescribe more in the contract. Too much freedom was given to the contractor, while the freedom was actually limited. That is why the client wants to frame the freedom more clearly, in retrospect, by prescribing the parts where there was no or limited freedom for the contractor.

The second place in the model is for the Design, Build & Maintain contract for this project. For the bridge a maintenance period of two years was included. This was done more as a guarantee for proper designing and building rather than actual maintenance. Furthermore, interviewee B mentioned that the contract type Bouwteam is interesting. As a client they prefer a contractor with a design and price that are in line with the market conditions rather than a cheap price. Bouwteam as a contract form is not incorporated in the model. However, it is a type of contract located in-between RAW-bestek and Design & Build (Centrum voor aansprakelijkheidsrecht, Universiteit van Tilburg, 2005). Meaning that the client and contractor work together in a team to create the design.
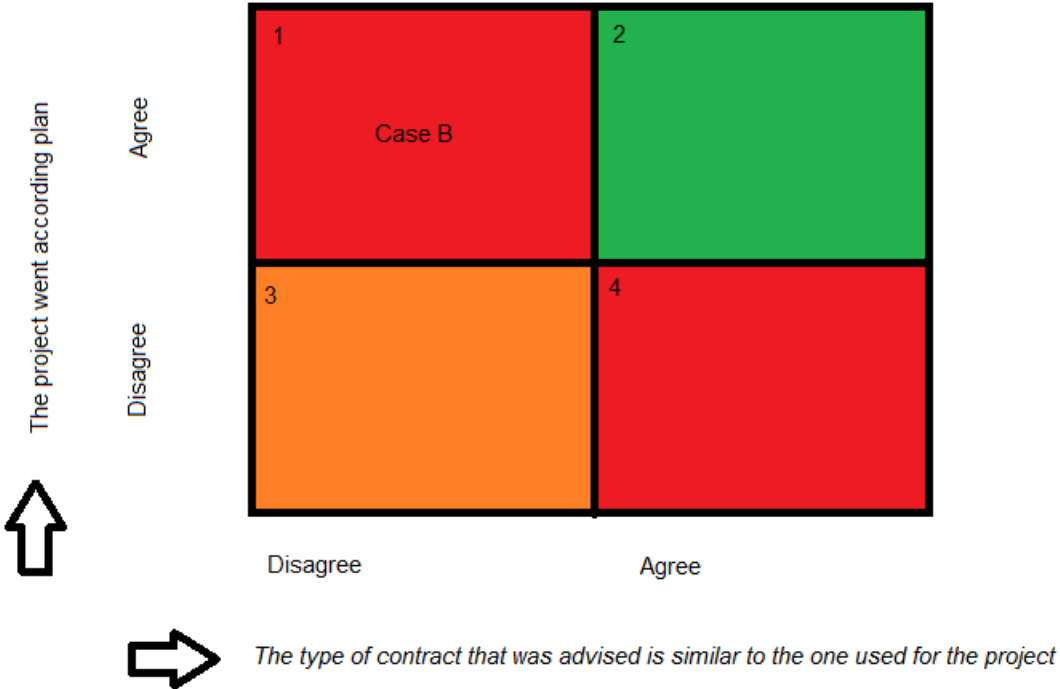


**Figure 7 Verification matrix case B**

All in all, the advice from the model does not correspond with the actual situation. But it does show the main headings that have matching benchmarks for other types of contracts than the contract that was used. This way the model can function as an informative model, showing the points of attention when choosing for a Design & Build contract.

### 5.2.3 Case C

For case C an interview is arranged with interviewee C who works for the client of this project and was involved from the beginning of the project. The involvement of interviewee C was from the beginning of the project, including the decision for the type of contract, until the completion of the project. This makes him very valuable for this verification. The new bridge is a replacement of the outdated old bridge. This old bridge was to small and the pressure for improvement of the situation rose, especially after a fatal traffic accident happened at the bridge. The old bridge was a drawbridge and the new bridge was determined to be a drawbridge too because it fits within the landscape. The new bridge is built next to the old bridge. This way the old bridge could stay in use while the new bridge was build. In a variant study (variantenstudie) this option turned out to be cheaper when compared to building the new bridge on the location of the old bridge and diverting the traffic over a temporary moveable bridge. As a consequence of this new location the roads leading to the bridge had to be rerouted. The total project encompassed the construction of the new bridge including the roads leading to the bridge, the construction of a roundabout and the widening of a part of the connecting roads.

### *The project*

For this project the contract type was Design & Construct, however the interviewee mentioned that it was more or less an Engineering & Construct since the architectural design was already established.

Design & Construct is comparable with Design & Build except that the architectural design was already established. Therefore, the Design & Construct contract is located in between the contract types RAW-bestek and Design & Build when looking at the degree of integration. The decision for this contract was (partially) based on the model that the client organisation uses. This model looks into the different disciplines involved in the project for deciding what type of contract to use. Furthermore, the strategy of the client organisation is to use an UAV-GC type of contract, unless project properties or specifications give reason to choose something else. In this project there was limited freedom for the contractor. The design was already determined, the execution method and the phasing of the project were the only points where the contractor could make a difference.

The mayor problem during this project was the availability of the building plots for the roads leading to the new bridge. This led to a serious delay in the project. Other points for improvement were uncertainties concerning underground cables at the project location and a discussion between the client and contractor about the profile of the road. The client eventually imposed a payment stop for the project in order to convince the contractor to focus more on the deviations of the project. Furthermore, the interviewee mentioned that the contractor had a low bid for this project. Due to the delay and discussion about the profile of the road the total sum (bid + claim by contractor) of the project is likely to rise to the average of the bids from all the contractors. The interviewee wonders if the contractors are ready for working with integrated contracts and the accompanying responsibilities. The contract however was satisfying for this project.

*Contract advise*

The contract advise from the model is Design & Build. The model as it was filled in by interviewee C can be seen in Appendix L. The advice from the model cannot corresponds with the contract that was used for this project since the contract types Design & Construct and Engineer & Construct are not included in the model. The interviewee mentioned that he would use the same type of contract for this project with hindsight knowledge but would allocate the risks differently. A risk should be located at the party that can best manage that specific risk.

The second place in the model is for the Design, Build & Maintain contract for this project. The difference between the first and second place in the contract advice model is minimal. Similar to the client of case B, this client also uses a maintain period after completion of the project. However, their maintain period is only one year and is implied for the same purpose of safeguarding proper design and construction by the contractor. A Design, Build & Maintain type of contract is actually not common for this client. After completion of a project the entire project is handed over to the asset management department, who, in turn, sign maintenance contracts for several years with contractors. The only difference in the benchmark scores between D&B and DBM concerns the desire to transfer risks to the contractor and the importance of low maintenance costs. The benchmarks for the contract type Design & Build match best with the most important main headings (time, quality, flexibility and risks).

The location of this case in the verification matrix (figure 5) is not unequivocally determined. The project needed control in order to get it going as planned. However, the type of contract that was used and the advised contract from the model have a lot in common. Furthermore, the third place in the model is for the contract type RAW-bestek. Similar to case A this contract scored high on the main heading external environment, highlighting the reasoning for establishing the architectural design.  This way the model shows the important main headings, main headings for which a Design & Construct type of contract is suited. Since Design & Construct as a contract type is not included in the model but the model shows the main headings for which a Design & Construct contract would score well, this verification is regarded as proving the functionality of the model. Therefore, this project could be located in quadrant 2 or 4 of the verification matrix. Quadrant 2 since the project in the end delivers what was planned and quadrant 4 since both client and contractor did not function as was planned. The client could not hand over the building plots to the contractor in time. While the contractor had to be 'encouraged' to perform as he had promised in the contract. The short comings of both parties were pushing the project towards quadrant 4 but the control from the contractor side managed to ensure the project to end up in quadrant 2. After all, the contract was satisfying for this project.
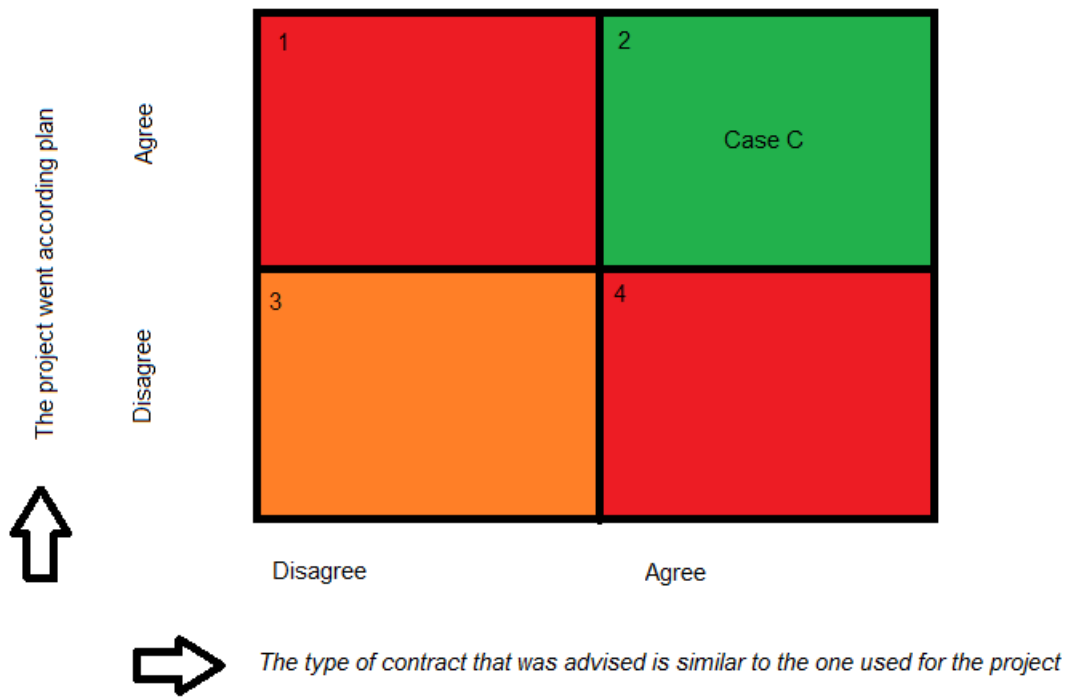
**Figure 8 Verification matrix case C**

To conclude, the advice from the model does not correspond with the contract that was actually used but it showed the main headings for which a Design & Construct contract would score well. The project delivered what was planned, however the path to this end result was sometimes difficult. This case shows that the model is functioning and shows for which types of contracts the important main headings have matching benchmarks.

### 5.2.4 Case D

For case D an interview was arranged with the project manager from the contractor. This contractor had done some projects for this client before. In a previous project the contractor noticed and informed the client that some renovation work must be done in the near future concerning the supports of the moveable part of the bridge. Time went by without any renovation being carried out. Until the client 'suddenly' noticed the problem, which at that time had already worsened when compared to the situation when the contractor informed the client. Due to the fact that the contractor had carried out works for this bridge for the client and the fact that the renovation had to take place soon led to the client and the contractor working together in a Bouwteam for the design part of the renovation. After this design phase the collaboration was changed to an UAV-GC (integrated) contract and the contractor carried out the renovation. The reason for changing the type of contract was based on the desire from the client to allocate risk at the contractor. An UAV-GC (integrated) type of contract suited that desire. The change of the type of contract for the execution was made in agreement between the client and the contractor. Furthermore, a contract sum could be stated for the project in the UAV-GC contract.

The contract strategy, starting with a Bouwteam and later on turning to the UAV-GC contract, have resemblance with an Design & Build contract. In which the Bouwteam start intensified the collaboration between client and contractor in the design phase. It was necessary to have the design available in time in order to be able to carry out the project in the pre-planned time span for which the bridge was planned to be out of service.

### *The project*

The collaboration in the team under the Bouwteam contract went good. This led to a well prepared plan and due to this the execution went according to plan. The time span for executing the project was limited. It had to be carried out in a pre-planned time span for which the bridge was planned to be out of service. Therefore time overrun was not an option. The client wanted to make sure that the plan, that was made together, would be carried out accordingly. They did this by means of a UAV-GC contract, which serves as a safety net, since the contractor can be held liable for executing his plan.

The clients staff in the Bouwteam consisted of people from different departments, their project division and the asset management. According to the interviewee, these departments were not always in line with their demands. They have different interests which can lead to mutual conflicts. This was not an ideal situation, but working in one team made it possible to solve these issues. Between the client and contractor some difficulties arose when the client wanted the guarantee that after the project was finished this problem would not reoccur. The contractor refused to give this guarantee since the source of this problem is in the design of the bridge and the contractor cannot be made liable for another party's design flaw. The execution of the project went according to plan and was finished within the available time span.

### Contract advise

The contract advise from the model is Design & Build. The model as it was filled in by interviewee D can be seen in Appendix M. This advice corresponds with the contract (strategy) that was used for this project, which the interviewee mentioned to be 'the logical type of contract for this project'. This locates this case in quadrant 2 of the verification matrix, the contract advise corresponds to a large extend with the type of contract that was used and the project went according plan. Particularly the main headings concerning *time* and *quality* scored high when compared with the other contracts in the model. The statement concerning *A contractor can take on a risk from the client* scored well too. Which all corresponds with what was mentioned by the interviewee: 'A team effort by the client and the contractor to make a sound plan on time and quality for the project where technique was predominant and later on a UAV-GC contract in order to have a clear distribution of the risks accompanied by a contract sum'.
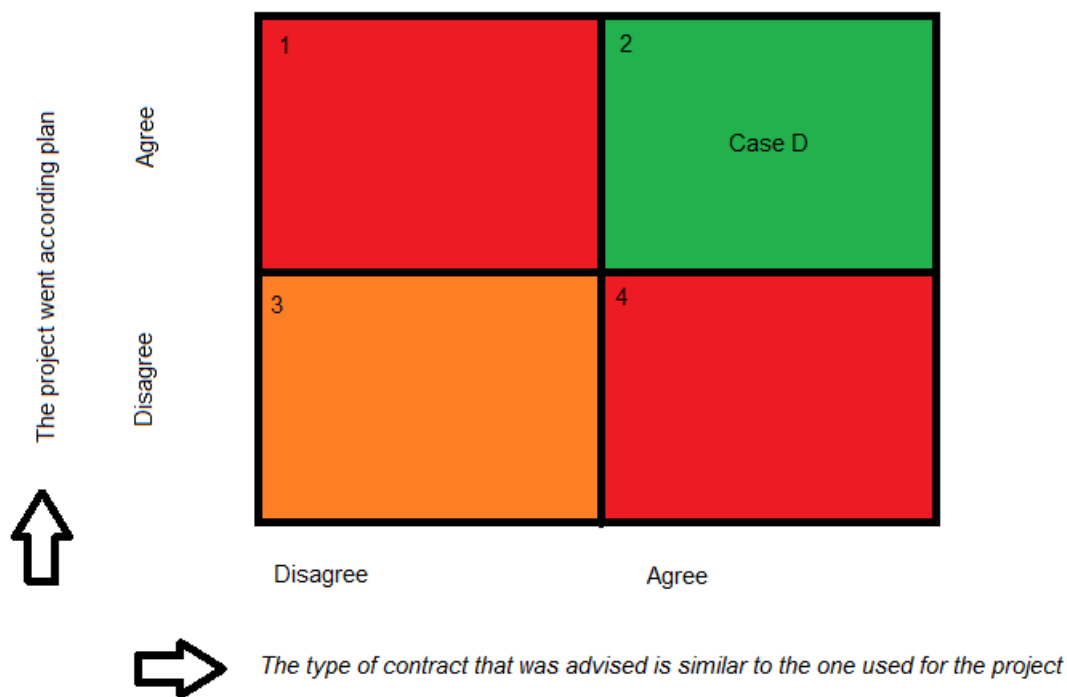


**Figure 9 Verification matrix case D**

To summarize, the advice from the model corresponds with the contract (strategy) that was actually used. The main headings that were of importance scored particularly well in the model for the Design & Build contract. This case shows that the model is functioning both in advising a type of contract as well as in showing for which types of contracts the important main headings have matching benchmarks.

### Remark

A minor mistake had occurred during this verification. The interviewee allocated in total 56 points over the different main headings, while 55 was the maximum amount of points to be allocated. However, the influence this mistake has on the result of the verification is negligible since the advice from the model would stay the same regardless of where one point would be subtracted. In order to prevent this from happening again a sum function is included in the first tab of the model which shows the total amount of points that is allocated over the different main headings.

## 5.3 Complexity adjusted model

In order to test the benchmark scores for the main heading of complexity, a comparison between the initial model and the initial model adjusted for complexity is made. For all the case projects the advice for the type of contract stayed the same.

For case A, B and D only the score for the contract form Turnkey changed, its total score was increased 5 points for case A and B and 7 points for case D. The only case where the total score for all the contract types changed was for case C. The contract types RAW-bestek, Design & Build and Design, Build & Maintain lost 5 points while Turnkey gained 5 points in the total score.

It is unclear at this point whether the benchmark scores for complexity should be adjusted or stay as they were, based on this comparison. It is recommended to further investigate this, ideally with a case that actually used a Turnkey contract or a case for which the initial model or the adjusted model advise a Turnkey contract. Since the contract type Turnkey was the one and only type of contract to score different due to the adjustments for the main heading of complexity.

# 6. Conclusion

## 6.1 Initial model

The goal of this research is to make a model that predicts which type of contract is best suited for a construction project. In order to reach this goal, the following sub-questions are defined.

### Sub-questions

1. Which project parameters are of influence on the procurement? (key parameters)
2. How is the (involvement of the) client of influence on the procurement? (client style)
3. Does the initial model, based on sub-questions 1 and 2, comply with real cases? (verification of the model)

Based on these sub-questions, the following conclusions can be drawn.

### Q1: Key parameters

According to the literature and interviews the following eleven main headings are of influence for the procurement:

- Cost
- Time
- Quality
- Flexibility
- Risk's
- Complexity
- Innovation
- Cost in the usage phase
- Involvement of the client
- External environment
- Client characteristics

This encompasses project characteristics, the external environment and client characteristics. These parameters are included in the contract advice model.

### Q2: Client style

The involvement of the client and the client characteristics influence the relation and way of collaborating between the client and the contractor. The level of experience of the client and whether it is a primary or secondary client are important factors. A client that does not want to be actively involved in the project is likely to use another type of contract than a client that wants to be involved in every part of the project. As for the client characteristics, inexperienced clients or clients without in-house capacity can benefit from the knowledge of a contractor. A matching contract can increase these benefits.

## Q3: Verification of the model

Three of the four verifications showed that the model is functioning, these projects were located in quadrant 2 in the verification matrix (figure 5). These projects are case A, C and D. For case A and C the contract advice model showed exactly for which statements the different contract forms scored well. The statements on which they scored well are exactly the items for which a Design & Construct and an Engineer & Construct type of contract would be suited. If these types of contracts type would have been incorporated in the model, they would most likely be advised by the model. Therefore, these cases are regarded as showing the proper functioning of the model.

The verification bases on case B is more difficult. The model is not advising a type of contract that matches the client's desires, while the project was not without its problems either. When the situation of the case B is compared with case A it is tempting to suggest improvements for case B, based on case A. Problems in the project of case B relate to the design phase and the freedom that was assigned to the contractors for this design. It could very well be the case that the availability of a preliminary design would have reduced the problems, since this preliminary design clarifies a lot of the things that turned out problematic for this project. Such as the suggested tunnel to cross a road while a viaduct had already been agreed on by the client and the owner of this road as a stakeholder. An Engineer & Construct type of contract or a Bouwteam start and later on turning it to an UAV-GC contract, similar to the case D, are promising suggestions. Other suggestions for improving the situation of case B all relate to the freedom in the design phase. The client might want to frame the freedom more clearly when using the Design & Build contract. It seems that the client and the contractor both had different expectations of working in the Design & Build way, they were not on the same level. Thereby, the client might have interpreted working with an integrated contract too much as letting things up to the contractor, explaining the freedom that was given. The client and the contractor could both have improved taking up their role in this Design & Build contract, as has happened during the project. The chosen type of contract could have been ideal for this project, however, the Design & Build contract was not used completely in the right manner. However, the model is not suggesting the ideal type of contract.

In order to improve the functionality of the model, the model should be expanded to accommodate more types of contracts and thereby increasing the probability of advising the correct type of contract. This increases the usability of the model too. It is suggested to at least incorporate the contract types Design & Construct, Engineer & Construct and Bouwteam in the model. The contract types that are currently included in this model are: RAW-bestek, Design & Build, Design, Build & Maintain and Turnkey. The decision to incorporate these four contract types is based on the fact to include traditional and integrated contracts and the availability of information concerning their parameters. RAW-bestek is the traditional contract type that is common to use for moveable bridges in the Netherlands. The choice for integrated contract types for moveable bridges is bigger. It was decided to include integrated contracts with different ranges of integration. Starting with Design & Build as a conventional integrated contract form followed by Design, Build & Maintain as a more integrated contract form and Turnkey as totally integrated contract form. It was decided to first verify the functionality of this model before expanding it with more contract types. The contract types Design & Construct, Engineer & Construct and Bouwteam would be located between RAW-bestek and Design & Build when looking at their level of integration. Contract types that are located in-between were not included in this model since the decision was made to focus on traditional and

integrated contracts. It was not clear on beforehand if and what other types of contracts should be included in the model.

## Remarks

Furthermore, interviews did not always go as planned. Interviewees might not want to share everything or may be unable to share everything due to confidentiality. All the interviewees were asked if it was okay to record the interview. The purpose of this recording was to not forget certain important parts of the interview when typing them out. This purpose was stated clearly on beforehand and it was emphasized that this recording would be treated confidential and would be deleted after this master thesis is finalised. Still, as soon as the recording started one of the interviewees seemed very cautious about what he said and how he said things. The interview did not go very smoothly and possible confidential information being recorded might have prohibited him from sharing his viewpoint. Therefore, the recording was stopped soon afterwards in order to still gain some knowledge from this interview. Despite the recording being stopped, the interview did not proceed as before the recording started. The verification interviews were not recorded to prevent this from happening.

Due to the number of interviewees for the parameters that are of influence for the type of contract, it is very unlikely that important information is not mentioned in the interviews. Therefore, the result of the interviews can be regarded as a valuable addition to the literature. On the other hand, the verification is based on four cases only. Verifying the model with more cases would result in a higher validity of the model.

Cognitive dissonance is unlikely to have occurred during the interviewees for the verification. The interviews are meant to gain knowledge concerning the advice of the model and the functionality of it. When looking back at the case interviews, it is very unlikely that cognitive dissonance has occurred. The reason for this is twofold. First due to the setup of the verification interview. The interviewees first filled in the model, the first phase of the verification. The advice from the model was not yet shown to them. Then the interviewee answered the questions concerning how the project went and what sort of contracts were considered before the project started. This is the second phase of the verification. After this the advice from the model was shown to them and they could give their opinion concerning this advice. In all the interviews it was already clear before the advice was shown whether or not this type of contract was considered. The second reason why it is unlikely that cognitive dissonance had occurred is based on the way the interviewees behaved during the verification. They were relaxed and by no means stressed or otherwise uncomfortable. The only way that the interviewee could manipulate the verification is by completely concealing something during all the three phases of the verification. Based on the setup of the verification and their behaviour and presence, the occurrence of cognitive dissonance is regarded as very unlikely. Therefore, the result from the verification cases is regarded as trustworthy and reliable.

## 6.2 Complexity adjusted initial model

Based on the results of the comparison between the initial model and the complexity adjusted initial model, it is not possible to prefer one model over the other. The decision was made to use the statements for flexibility that are in line with the Dutch guideline (Chao-Duivis, Koning, & Ubink, 2013) (Centrum voor aansprakelijkheidsrecht, Universiteit van Tilburg, 2005) and to use the viewpoint for complexity from the articles 'Which procurement system' Skitmore & Marsden (1988), 'A comparison of contractual arrangements for building projects' (Nahapiet & Nahapiet, 2006) and 'Playing with complexity' (Hertogh & Westerveld, 2010). The viewpoint from these articles was preferred over the article 'An analytical hierarchy process based procurement selection method' (Cheung, Lam, Leung, & Wan, 2001). The reasons for this is based on the fact that the three articles mention the same positive correlation while only Cheung, Lam, Leung, & Wan (2001) contradict to this.

Based on the verifications there is no reason to adjust the other benchmark scores of the initial model. Furthermore, the setup of the model, using the two tabs in which the client assigns his weightings and scores and one tab in which the advise for a type of contract is generated, proved to function. Due to this and the comparison between the models, the initial model, without the adjustments for complexity, is chosen as the final model. However, it is recommended to further investigate the correlation between flexibility and complexity and the influence for the contract advice model. It is suggested to investigate this with the use of a case that actually used a Turnkey contract or a case for which the initial model or the adjusted model advise a Turnkey contract. Since the contract type Turnkey was the one and only type of contract to score different due to the adjustments for the main heading of complexity in all the four verification cases.

## 6.3 Answer to the research question

The goal of this research is to make a model that predicts which type of contract is best for a moveable bridge project. The contract advice model has a lot of potential for advising clients in their decision for a type of contract. To answer the research question, the model proved to function for moveable bridges, but it is insufficient substantiated to conclude that it is fully functional based on four cases only. More research and verifications should prove the full functionality of the model. To increase the usability and applicability of the model, verification with more moveable bridges cases should be done.

In this research only moveable bridge projects are taken into account, these are specific types of construction projects. The following four reasons for limiting this research to moveable bridges alone were evident. The variety of types of construction projects forced this research to focus on one type of project, in order not to become too comprehensive. The ability to compare the results between the verifications in detail since only one type of project is researched. Furthermore, moveable bridges are multidisciplinary projects which makes the decision for a specific type of contract ambiguous. Lastly, the availability of cases for verifying the initial model was of influence too for limiting this study to moveable bridges only.

Furthermore, it is important to keep in mind that models only capture reality partially. It is important to keep this in mind. The decision for a type of contract should never be based on the outcome of a model solely. The usage of models is limited in this respect. As mentioned in chapter 2.2.4, it is not possible to advise an optimal procurement strategy for every project based on an exclusive set of criteria. There might be something peculiar to a project which is too unique to capture in a model. Therefore, common sense and knowledge should be used with regards to the advice from the model. The outcome of the model only functions as an advise. It helps the client to really consider and weigh the different aspects of a project for their relative importance. The result of the model, the advise, is as good and trustworthy as the input that is used to generate this outcome. Therefore, no rights can be derived from the outcome of the model.

# 7. Recommendations

The recommendations are formulated based on the conclusion. The goal of the recommendations is to indicate which actions should be taken in order to improve the model.

It was concluded that the types of contracts included in the model were not comprehensive. Therefore, it is recommended to expand the contract advice model with more contract types, such as the contract types Design & Construct,  Engineer & Construct and Bouwteam. Possibly more types of contracts should be included in the model. Research into the corresponding benchmark scores for these types of contracts must be done too. Additionally, it should be investigated if more main headings should be included in the model when extra types of contracts are incorporated. It might be possible that these extra types of contracts require adding other main headings and criteria. Which implies additional research into the corresponding benchmark scores for the types of contracts that are already included in the model.

Furthermore, the conclusion showed that there is uncertainty concerning the benchmark score for complexity for the contract type Turnkey. The positive correlation between complexity and flexibility was stated in literature, meaning that when the complexity of the project increases the need for more flexibility also increases. The investigated articles, however, did have contradicting statements for the benchmark scores for complexity; it was unclear which viewpoint should be preferred. The benchmark scores for flexibility were based on the Dutch guideline, therefore, the decision was made to adopt the positive correlation for the initial model. After verifying this initial model, the benchmark scores for complexity were adjusted in order to be in line with the viewpoint from Cheung, Lam, Leung, & Wan (2001). The advice from the initial model and the initial model adjusted for complexity were compared. However, based on this comparison no firm conclusion can be made which prefers one viewpoint over the other. Therefore, it is recommended to further investigate the correlation between flexibility and complexity and adjust the model if necessary. It is suggested to investigate this with the use of a case that actually used a Turnkey contract or a case for which the initial model or the adjusted model advise a Turnkey contract. Since the literature was contradictory in the benchmark scoring for complexity for the contract type Turnkey. Thereby, the contract type Turnkey was the one and only type of contract to score different due to the adjustments for the main heading of complexity in all the four verification cases. While the benchmark scores for complexity were adjusted for all the contract types in this adjusted model.

Another recommendation concerns the manner in which the calculation is executed in the third tab of the model to come up with the advise. Currently, when the clients scoring for a statement and the benchmark for that statement match, then the weighting factor for that statement is multiplied by 1. Resulting in a total score for that statement identical to its weighting factor. In case the scoring for a statement by the client and the benchmark for that statement don't match then the weighting factor for that statement is multiplied by 0. Resulting in a total score of 0 for that statement. The sum of all these multiplications for every type of contract is calculated. The type of contract with the highest sum is the advised type of contract. It is recommended to perform a sensitivity analysis to investigate the sensitivity of the model to changes in input variables. This sensitivity analysis must show whether multipliers in between 1 and 0 could be used to increase the usability of the model. Possibly by assigning, for instance, a multiplier of 0,5 to a neighbouring benchmark. For example, the first statement, 'Certainty of the total cost in an early stage is important', for the main heading cost has benchmark score 'Completely agree'. The sensitivity analysis must highlight whether it is feasible to, for instance, assign a multiplier of 0,5 to the neighbouring benchmark 'Agree', in order to improve the model.

Last but not least, as mentioned in the conclusion, the model is only verified for four moveable bridges. More moveable bridges projects and other types of construction projects should be used to further verify the model in order to increase the usability and applicability of the model. Therefore, the last recommendation is to further verify the contract advice model. This verifying should be done with moveable bridge projects and other types of construction projects. More moveable bridge verifications must consolidate the proper functioning of the model for moveable bridges. Verifying the model with other types of construction projects must ensure a wider applicability of the model. Potential other types of construction projects for verification encompass utility construction, sluices and sewage treatment plants.

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# 9. Appendices

A: Overview of procurement criteria per literature and interview

B: Interview 1 (confidential)

C: Interview 2 (confidential)

D: Interview 3 (confidential)

E: Interview 4 (confidential)

F: Interview 5 (confidential)

G: Interview 6 (confidential)

H: Interview 7 (confidential)

I: Interview 8 (confidential)

J: Verification case A (confidential)

K: Verification case B (confidential)

L: Verification case C (confidential)

M: Verification case D (confidential)

N: Contract advice model (initial and complexity adjusted)

Overview procurement criteria per literature and interview

| Main heading | Criteria | NEDO 1985 | Which procurement system — Skitmore R.M. & Marsden D 1988 | Client characteristics and needs in relation to their selection of building procurement systems — J.W.E. Masterman & R.N. Gameson 1994 | Influence of the client, designer and procurement methods on project performance — S.G. Naoum & F.H. Mustapha 1994 | An analytical hierarchy process based procurement selection method — cheung, s., lam, t., leung, m. 2001 | Parameters governing the selection of procurement system - an empirical survey — Duc Thanh Luu, S. Thomas 2003 | Formulating procurement selection criteria through case-based reasoning approach (general criteria are mentioned, extra criteria that are project bounded should be) — Duc Thanh Luu, S. Thomas Ng, See E 2005 | A comparison of contractual arrangements for building projects — Nahapiet & Nahapiet 2006 | Participatory action research approach to public sector procurement selection (=NEDO CRITERIA MET WEGINGSFACTOR) — Love, P., edwards, d., irani, z. and 2012 | Modern selection criteria for procurement methods — Shamil George Naoum an 2015 | Contractering bij bouwprojecten — Hans de Koning and Will Sproncken 2001 | Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria (included for comparison with the investigated articles) — R. Atkinson 1999 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Time | | | | Total time (design + build time) | | | | | | | | X |
| | Speed (early completion) | X | 1 | | | X | | X | X | X | X | X | |
| | Time certainty | X | | X | | | | X | X | X | X | | |
| | On-time completion | | | | | | 2 | X | | | | | |
| | Pre-construction time | | | | X | | | | | | | | |
| | Time overrun | | | | X | | | | | | | | |
| | Client satisfaction on time | | | | X | | | | | | | | |
| Cost | Cost | | | | | | | | | | | | X |
| | Cost certainty | X | | X | | X | | X | | X | X | | X |
| | Price competition | X | 4 | X | | X | | X | | | | | |
| | Tight cost | | | | | | | | X | | | | |
| | Within budget completion | | | | | | | 1 | X | | | | |
| | Unit cost | | | | X | | | | | | | | |
| | Cost overrun | | | | X | | | | | | | | |
| | Certainty (over time and cost) | X | 2 | | | | | | | | | | |
| | Value for money | | | X | | | 3 | | | | | | |
| Quality | Quality of the end product | X | | | | X | | X | | | | | |
| | Quality of the process | X | | | | | | X | | | X | | X |
| Flexibility | Flexibility | X | 6 | | | | | X | | | | | |
| | Possible flexibility and variations | | | | | X | | | X | | X | X | |
| Risk (allocation/responsibi | Risk avoidance and responsibility | | 3 | | | X | | | | | | | |
| | Risk allocation | X | | | | | | X | | X | | X | |
| | Clients willingness to take risks | | | | | | 7 | X | | | | | |
| | Level of risk to the clients | | | | | | | | | | | | |
| | Responsibility | X | | | | | | X | | X | X | X | |
| | Clear division of roles and responsibilities | | | | | X | | X | | X | X | | |
| | Unknown site risk factors | | | | | | 23 | | | | | | |
| | Known site factors likely to cause problems | | | | | | 10 | X | | | | | |
| | Safety issues | | | | | | | | | | X | | |
| Complexity | Building complexity | | 7 | | | | | | | | | | |
| | Complexity, the suitability of the procurement method in handling complex projects | | | | | X | | | | | | | |
| | Complexity | X | | | | | | X | | X | X | | |
| | Size of project | | | | | | 5 | X | | | | | |
| | Project type | | | | | | 4 | X | | | | | |
| | Building construction type | | | | | | 15 | X | | | | | |
| Innovation | Project requirements | | | | | | | | X | | | | |
| | Need for buildability | | | | | | | | | | | | |
| | Need for creativity and innovation in the design | | | | | | | | | | X | | |
| | Importance of sustainability in design and material | | | | | | | | | | X | | |
| | Highly serviced or technically advanced building | | | | | | 20 | X | | | | | |
| | Clients requirement for aesthetic building | | | | | | 24 | X | | | | | |
| | Usage of pioneering technology | | | | | | 27 | | | | | | |
| Modern concepts/tools | Importance of utilizing the supply chain concept | | | | | | | | | | X | | |
| | Facilitating lean construction | | | | | | | | | | X | | |
| | Application of value engineering | | | | | | | | | | X | | |
| | Need for the application of BIM | | | | | | | | | | X | | |
| | Need for e-procurement | | | | | | | | | | X | | |
| Cost during the usage phas | Importance of operating and maintenance costs | | | | | | | | | | X | | |
| | Low maintenance cost | | | | | | 18 | | | | | | |
| | Low operational cost | | | | | | 17 | | | | | | |
| Involvement of the client | Kept informed and actively involved at all stages of the project | | | X | | | | | | | | | |
| | Clients willingness to be involved | | | | | | 13 | X | | | | | |
| Relational | Contractual relations and legal relations between parties | | | | | | | | | | | | |
| | Functional relations between parties | | | | | | | | X | | | X | |
| | Phasing of the building process and the time of participation of parties | | | | | | | | X | | | X | |
| | **External environment factors** | | | | | | | | | | | | |
| External environment | Technology feasibility | | | | | | 11 | | | | | | |
| | Regulatory feasibility | | | | | | 21 | | | | | | |
| | Materials availability | | | | | | 22 | | | | | | |
| | Availability of experienced contractor | | | | | | 8 | X | | | | | |
| | Labour productivity | | | | | | 28 | | | | | | |
| | Industrial actions | | | | | | 26 | | | | | | |
| | Markets competitiveness | | | | | | 6 | X | | | | | |
| | Political constrains | | | | | | 25 | | | | | | |
| | Stakeholders | | | | | | | | | | | | |
| | Bestemmingsplan | | | | | | | | | | | | |
| | **Client characteristics** | | | | | | | | | | | | |
| Client characteristics | Client characteristics in literatuur | | | indeling secondary of primary developer en experienced/inexperienced | Client indeling op blz 222Experience of the building team with the building proces has significantly influenced the time and cost overruns, as well as the quality standard of the project. | | | | | | | | |
| | Clients experience | | | X | | | 12 | X | X | | | | |
| | Client type (primary/secondary) | | | X | | | 16 | X | X | | | | |
| | Clients trust towards other parties | | | | | | 9 | X | | | | | |
| | Clients financial capability | | | | | | 18 | | | | | | |
| | Clients in-house technical capabilities | | | | | | 14 | X | X | | | | |

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| # | Main heading | Criteria | Interview 1 | Interview 2 | Interview 3 | Interview 4 | Interview 5 | Interview 6 | Interview 7 | Interview 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Criteria** | **Criteria from interv ev** | | | | | | | |
| 3 | Main heading | Criteria | | | | | | | | |
| 4 | Time | Time | x | x | x | | | Time pressure on tenders | | x |
| 5 | | Speed (early completion) | | | | | | | | |
| 6 | | Time certainty | | x | | | | | | |
| 7 | | On-time completion | | | x | x | | | x | |
| 8 | | Pre-construction time | | | | | | | x | |
| 9 | | Time overrun | | | | | | | | |
| 10 | | Client satisfaction on time | | | | | | | | |
| 11 | | Cost | x | x | x | | | | x | x |
| 12 | | Cost certainty | | | | | | | | |
| 13 | | Price competition | | | x | | | | | x |
| 14 | | Tight cost | | | | x | | | | x |
| 15 | | Within budget completion | | x | | x | | | | |
| 16 | | Unit cost | | | | | | | | |
| 17 | | Cost overrun | | | | | | | | |
| 18 | | Certainty (over time and cost) | | | | | x | | | |
| 19 | | Value for money | | | | | | | | |
| 20 | Quality | Quality of the end product | x | x | x | | x | | x | |
| 21 | | Quality of the process | x | x | | | x | | | |
| 22 | Flexibility | Flexibility | | | | | | | | |
| 23 | | Possible flexibility and variations | x | | | | | | | |
| 24 | Risk (allocation/responsibil | Risk avoidance and responsibility | | | x | | | | | |
| 25 | | Risk allocation | x | | x | | x | x | | x |
| 26 | | Clients willingness to take risks | | | | | | | | |
| 27 | | Level of risk to the clients | | | x | | | | x | x |
| 28 | | Responsibility | | | | | x | x | | |
| 29 | | Clear division of roles and responsibilities | | | x | | | | | |
| 30 | | Unknown site risk factors | | | x | | | | | |
| 31 | | Known site factors likely to cause problems | | | x | | | | | |
| 32 | | Safety issues | | | | | | x | | |
| 33 | Complexity | Building complexity | | | | | | | | |
| 34 | | Complexity, the suitability of the procurement method in handling complex projects | | | | | | | | |
| 35 | | Complexity | | x | x | x | | | | |
| 36 | | Size of project | | | | | x | | | |
| 37 | | Project type | | | | | | | | |
| 38 | | Building construction type | | | | | | | | |
| 39 | Innovation | Project requirements | | | | Is there the possibility for innovation b | x | x | | |
| 40 | | Need for buildability | | | | | x | | | |
| 41 | | Need for creativity and innovation in the design | | | x | x | x | | | |
| 42 | | Importance of sustainability in design and material | x | | | x | x | | | |
| 43 | | Highly serviced or technically advanced building | | | | | | | | |
| 44 | | Clients requirement for aesthetic building | | | | | x | | | |
| 45 | | Usage of pioneering technology | | | | | usage of proven technology | | | |
| 46 | Modern concepts/tools | Importance of utilizing the supply chain concept | | | | | | | | |
| 47 | | Facilitating lean construction | | | | | | | | |
| 48 | | Application of value engineering | | | | | | | | |
| 49 | | Need for the application of BIM | | | | | | | | |
| 50 | | Need for e-procurement | | | | | | | | |
| 51 | Cost during the usage phas | Importance of operating and maintenance costs | | | | | optimal management and maintenance | | | |
| 52 | | Low maintenance cost | | | | | | | | |
| 53 | | Low operational cost | | | | | | | | |
| 54 | Involvement of the client | Kept informed and actively involved at all stages of the project | | | | | | | x | |
| 55 | | Clients willingness to be involved | | | | | | | x | |
| 56 | Relational | Contractual relations and legal relations between parties | | | | | | | | |
| 57 | | Functional relations between parties | | x | | | | | | |
| 58 | | Phasing of the building process and the time of participation of parties | | x | | | | | | |
| 59 | | | | | | | | | | |
| 60 | | **External environment factors** | | | | | | | Political decision making | Permits |
| 61 | External environment | Technology feasibility | | | | | | | | |
| 62 | | Regulatory feasibility | | | | | | | | |
| 63 | | Materials availability | | | | | | | | |
| 64 | | Availability of experienced contractor | | | | | | | | |
| 65 | | Labour productivity | | | | | | | | |
| 66 | | Industrial actions | | | | | | | | |
| 67 | | Markets competitiveness | | | | | | | | |
| 68 | | Political constrains | | | | | | | | |
| 69 | | Stakeholders | | x | x | x | x | | | x |
| 70 | | Bestemmingsplan | | | x | x | | | | |
| 71 | | | | | | | | | | |
| 72 | | **Client characteristics** | | | | | | | | |
| 73 | Client characteristics | Client characteristics in literatuur | | Comm Communication | | Capacity and organization of the client | | | | |
| 74 | | Clients experience | x | | | | | | x | |
| 75 | | Client type (primary/secondary) | | | | | | | | |
| 76 | | Clients trust towards other parties | | x | | | | | | |
| 77 | | Clients financial capability | | | | | | | | |
| 78 | | Clients in-house technical capabilities | x | | x | x | | | x | x |
| 79 | | | | | | | | | | |

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## Appendix B
Interview 1


## Appendix C
Interview 2


## Appendix D
Interview 3


## Appendix E
Interview 4


## Appendix F
Interview 5


## Appendix G
Interview 6


## Appendix H
Interview 7


## Appendix I
Interview 8

## Appendix J
Verification case A

## Appendix K
Verification case B

## Appendix L
Verification case C

## Appendix M
Verification case D

# Appendix N

Contract advice model (initial and complexity adjusted)

## Tab 1: Weighting factor for the main headings

| | A | B | C |
|---|---|---|---|
| 1 | Explanation for weighting factors: | | |
| 2 | The weighting factor is on a scale from 1 to 10. If there is no distinction between the weighting per main heading, the same number must be entered for all main headings. It doesn't matter what number this is. | A total of 55 points can be distributed | |
| 3 | **Main heading** | **Weighting factor** | |
| 4 | Cost | | |
| 5 | Time | | |
| 6 | Quality | | |
| 7 | Flexibility | | |
| 8 | Risks | | |
| 9 | Complexity | | |
| 10 | Innovation | | |
| 11 | Costs in the usage phase | | |
| 12 | Involvement of the client | | |
| 13 | External environment | | |
| 14 | Client characteristics | | |
| 15 | | 1 | |
| 16 | | 2 | |
| 17 | | 3 / 4 | |
| 18 | Total number of points awarded | 5 / 6 | |
| 19 | | 7 | |
| 20 | | 8 | |

## Tab 2: Scoring per statement for every main heading

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Main heading | Statement | Input field | |
| 2 | Cost | Certainty of the total costs in an early stage is important | | |
| 3 | Cost | Pure price competition is desirable | | |
| 4 | | | | |
| 5 | Time | Certainty of delivering the project before or on a fixed delivery date is important | | |
| 6 | Time | The desire of achieving the shortest time span for the project (design + build time) | | |
| 7 | | | | |
| 8 | Quality | The quality of the end product should be above average, even if this implies extra costs | | |
| 9 | Quality | The quality in the design process is of importance to the client | | |
| 10 | | | | |
| 11 | Flexibility | The possibility for changes in the design phase is desired | | |
| 12 | Flexibility | The possibility for changes in the constructions phase is desired | | |
| 13 | | | | |
| 14 | Risks | A contractor can take on a risk from the client | | |
| 15 | Risks | Transfer of risks from the client to the contractor is desirable | | |
| 16 | | | | |
| 17 | Complexity | The project is highly specialized or technologically advanced | | |
| 18 | Complexity | The project has high performance requirements | | |
| 19 | | | | |
| 20 | Innovation | The space for the contractor to come up with innovative or alternative solutions | | |
| 21 | Innovation | Usage of proven technology is desirable | | |
| 22 | | | | |
| 23 | Costs in the usage phase | Low maintenance cost in the usage phase are important (life cycle costing is part of the clients decision making) | | |
| 24 | Costs in the usage phase | Low operational cost are important in relation to the investment cost | | |
| 25 | | | | |
| 26 | Involvement of the client | It is important to be kept up to date and involved in all the stages of the project | | |
| 27 | Involvement of the client | Does the client trust other parties, in order to be less involved | | |
| 28 | | | | |
| 29 | External environment | Stakeholders have influence on the project | | |
| 30 | External environment | The surrounding environment imposes limitations on the project | | |
| 31 | | | | |
| 32 | Client characteristics | Does the clients has experience with building similar projects | | |
| 33 | Client characteristics | The clients has in-house expertise to design | | |
| 34 | | | Completely agree | |
| 35 | | | Agree | |
| 36 | | | Neutral | |
| 37 | | | Disagree | |
| 38 | | | Completely disagr | |

Tab 3: Benchmark scores for the initial model

| Main heading | Statement | Input field | Weighting factor | RAW-bestek | RAW score | RAW Score*W | Design & Build | DB score | DB Score*W | Design, Build & Maintenance | DBM score | DBM Score*W | Turnkey | TK score | TK Score*W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost | Certainty of the total costs in an early stage is important | 0 | 0 | 0 Completely agree | 0 | 0 | 0 Agree | 0 | 0 | 0 Agree | 0 | 0 | 0 Agree/Neutral | 0 | 0 |
| Cost | Pure price competition is desirable | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Neutral/Disagree | 0 | 0 |
| Time | Certainty of delivering the project before or on a fixed delivery date is important | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 |
| Time | The desire of achieving the shortest time span for the project (design + build time) | 0 | 0 | 0 Disagree/Completely disagree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree | 0 | 0 |
| Quality | The quality of the end product should be above average, even if this implies extra costs | 0 | 0 | 0 Agree/neutral | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely disagree | 0 | 0 |
| Quality | The quality in the design process is of importance to the client | 0 | 0 | 0 Neutral/Disagree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 |
| Flexibility | The possibility for changes in the design phase is desired | 0 | 0 | 0 Completely agree/agree | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Completely disagree | 0 | 0 |
| Flexibility | The possibility for changes in the constructions phase is desired | 0 | 0 | 0 Neutral/Disagree | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Completely disagree | 0 | 0 |
| Risks | A contractor can take on a risk from the client | 0 | 0 | 0 Disagree/Completely disagree | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree | 0 | 0 |
| Risks | Transfer of risks from the client to the contractor is desirable | 0 | 0 | 0 Neutral/Disagree | 0 | 0 | 0 Agree | 0 | 0 | 0 Completely agree | 0 | 0 | 0 Completely agree | 0 | 0 |
| Complexity | The project is highly specialized or technologically advanced | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Completely disagree | 0 | 0 |
| Complexity | The project has high performance requirements | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Completely disagree | 0 | 0 |
| Innovation | The space for the contractor to come up with innovative or alternative solutions | 0 | 0 | 0 Disagree/Completely disagree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Completely agree/Disagre | 0 | 0 | 0 Completely agree/Agree | 0 | 0 |
| Innovation | Usage of proven technology is desirable | 0 | 0 | 0 Agree | 0 | 0 | 0 Neutral/Disagree | 0 | 0 | 0 Neutral/Disagree | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| Costs in the usage phase | Low maintenance cost in the usage phase are important (life cycle costing is part of the clients decision making) | 0 | 0 | 0 Neutral | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| Costs in the usage phase | Low operational cost are important in relation to the investment cost | 0 | 0 | 0 Agree/Neutral | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| Involvement of the client | It is important to be kept up to date and involved in all the stages of the project | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Neutral/Disagree | 0 | 0 | 0 Neutral/Disagree | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| Involvement of the client | Does the client trust other parties, in order to be less involved | 0 | 0 | 0 Disagree/Completely disagree | 0 | 0 | 0 Agree | 0 | 0 | 0 Completely agree | 0 | 0 | 0 Completely agree/Agree | 0 | 0 |
| External environment | Stakeholders have influence on the project | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Disagree/Completely Disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| External environment | The surrounding environment imposes limitations on the project | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Disagree/Completely Disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| Client characteristics | Does the clients has experience with building similar projects | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Disagree/Completely Disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| Client characteristics | The clients has in-house expertise to design | 0 | 0 | 0 Completely agree/Agree | 0 | 0 | 0 Disagree/Completely Disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 | 0 Disagree/Completely disag | 0 | 0 |
| | | | | | Sum | | | | Sum | | | Sum | | | Sum |
| | | | | | | 0 | | | | 0 | | | 0 | | | 0 |

Tab 4: Benchmark scores for the complexity adjusted model

| | Main heading | Statement | Input field | Weighting factor | RAW-bestek | RAW score | RAW Score*W | Design & Build (Design & Construct) | DB score | DB Score*W | Design, Build & Maintenance | DBM score | DBM Score*W | Turnkey | TK score | TK Score*W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Cost | Certainty of the total costs in an early stage is important | 0 | 0 | Completely agree | 0 | 0 | Agree | 0 | 0 | Agree | 0 | 0 | Agree/Neutral | 0 | 0 |
| 4 | Cost | Cure price competition is desirable | 0 | 0 | Completely agree/Agree | 0 | 0 | Agree/Neutral | 0 | 0 | Agree/Neutral | 0 | 0 | Neutral/Disagree | 0 | 0 |
| 5 | | | | | | | | | | | | | | | | |
| 6 | Time | Tertainty of delivering the project before or on a fixed delivery date is important | 0 | 0 | Agree/Neutral | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 7 | Time | The desire of achieving the shortest time span for the project (design + build time) | 0 | 0 | Disagree/Completely disa | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree | 0 | 0 |
| 8 | | | | | | | | | | | | | | | | |
| 9 | Quality | Che quality of the end product should be above average, even if this implies extra costs | 0 | 0 | Agree/neutral | 0 | 0 | Agree/Neutral | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely disagree | 0 | 0 |
| 10 | Quality | Che quality in the design process is of importance to the client | 0 | 0 | Neutral/Disagree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 11 | | | | | | | | | | | | | | | | |
| 12 | Flexibility | Fhe possibility for changes in the design phase is desired | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely disagree | 0 | 0 |
| 13 | Flexibility | Fhe possibility for changes in the constructions phase is desired | 0 | 0 | Neutral/Disagree | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely disagree | 0 | 0 |
| 14 | | | | | | | | | | | | | | | | |
| 15 | Risks | F contractor can take on a risk from the client | 0 | 0 | Disagree/Completely disag | 0 | 0 | Agree/Neutral | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree | 0 | 0 |
| 16 | Risks | Fransfer of risks from the client to the contractor is desirable | 0 | 0 | Neutral/Disagree | 0 | 0 | Agree | 0 | 0 | Completely agree | 0 | 0 | Completely agree | 0 | 0 |
| 17 | | | | | | | | | | | | | | | | |
| 18 | Complexity | Che project is highly specialized or technologically advanced | 0 | 0 | Neutral | 0 | 0 | Neutral | 0 | 0 | Neutral | 0 | 0 | Agree | 0 | 0 |
| 19 | Complexity | Che project has high performance requirements | 0 | 0 | Neutral | 0 | 0 | Agree | 0 | 0 | Agree | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 20 | | | | | | | | | | | | | | | | |
| 21 | Innovation | lihe space for the contractor to come up with innovative or alternative solutions | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely agree/Agree | 0 | 0 | Completely agree/Disagre | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 22 | Innovation | Hsage of proven technology is desirable | 0 | 0 | Agree | 0 | 0 | Neutral/Disagree | 0 | 0 | Neutral/Disagree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 23 | | | | | | | | | | | | | | | | |
| 24 | Costs in the usage phase | Cow maintenance cost in the usage phase are important (life cycle costing is part of the clients decision making) | 0 | 0 | Neutral | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 25 | Costs in the usage phase | Cow operational cost are important in relation to the investment cost | 0 | 0 | Agree/Neutral | 0 | 0 | Disagree/Completely disag | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 26 | | | | | | | | | | | | | | | | |
| 27 | Involvement of the client | Iit is important to be kept up to date and involved in all the stages of the project | 0 | 0 | Completely agree/Agree | 0 | 0 | Neutral/Disagree | 0 | 0 | Neutral/Disagree | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 28 | Involvement of the client | Hoes the client trust other parties, in order to be less involved | 0 | 0 | Disagree/Completely disag | 0 | 0 | Agree | 0 | 0 | Completely agree | 0 | 0 | Completely agree/Agree | 0 | 0 |
| 29 | | | | | | | | | | | | | | | | |
| 30 | External environment | Etakeholders have influence on the project | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 31 | External environment | Ehe surrounding environment imposes limitations on the project | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 32 | | | | | | | | | | | | | | | | |
| 33 | Client characteristics | Ooes the clients has experience with building similar projects | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 34 | Client characteristics | Che clients has in-house expertise to design | 0 | 0 | Completely agree/Agree | 0 | 0 | Disagree/Completely Disag | 0 | 0 | Disagree/Completely disag | 0 | 0 | Disagree/Completely disag | 0 | 0 |
| 35 | | | | | | | | | | | | | | | | |
| 36 | | | | | | Sum | | | Sum | | | Sum | | | Sum | |
| 37 | | | | | | | 0 | | | 0 | | | 0 | | | 0 |
| 38 | | | | | | | | | | | | | | | | |